Tables of Element Values for the Distributed Low-Pass Prototype Filter

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Abstract—An exact general synthesis for the distributed stepped-impedance low-pass prototype filter is presented here. Tables of values of the step impedances of filters having Chebyshev equal-ripple characteristics are given for up to 21 elements over a wide range of bandwidths and ripple levels. The tables are useful for the design of short-line low-pass filters, direct-coupled cavity filters, stepped-impedance acoustic or optical filters, impedance transformers, and branched guide directional couplers, as described in the papers of L. Young.

I. Introduction

THE N-ELEMENT stepped-impedance transformer has been used by Young as a prototype for the design of direct-coupled filters [1]–[4]. Tables for the element values of this prototype were published up to $n=4$ for the Chebyshev equal-ripple response and up to $n=8$ for the Butterworth or maximally-flat response. Chebyshev filters with more than 4 elements are frequently required, and previously it has been necessary to use approximations to obtain these prototypes [3], [5]. It is considered more satisfactory to use an exact prototype, leading to improved accuracy in the final practical component, so that the publication in this paper of accurate tables for all values of n up to 21 simplifies the design of filters and transformers by Young's method. Here the low-pass (or half-wave) filter (LPF) has been used as the prototype rather than the stepped-impedance transformer (SIT). Since these are directly related [2] it is immaterial which one is used as the protype for component synthesis. The LPF was chosen because the impedances of successive steps alternately increase and decrease, usually oscillating about unity. The step impedances are quite small in numerical value. In the case of the SIT the impedances increase monotonically from unity, often to extremely large values, possibly 10^{20} or more. A solution to this difficulty would be to tabulate junction VSWRs [3] rather than step impedances, but with the method of synthesis adopted here, this solution would lead to other difficulties (see Section IV).

Section II describes the synthesis procedure, and may be omitted by readers not interested in the mathematical details.

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II. Synthesis Procedure

The form of the LPF is shown in Fig. 1, and the insertion loss in Fig. 2 for the case of Chebyshev equal ripple response. The insertion loss is given by

$$L = 1 + h^2 T_n^2 \left(\frac{\sin\theta}{\sin\theta_0}\right) \tag{1}$$

where T_n denotes the Chebysev function of the first kind of degree n. The synthesis of this function is similar to that described in previous papers [6], [7]. The power reflection coefficient is

$$|\Gamma|^2 = \frac{L-1}{L} = \frac{h^2 T_n^2 \left(\frac{\sin\theta}{\sin\theta_0}\right)}{1 + h^2 T_n^2 \left(\frac{\sin\theta}{\sin\theta_0}\right)}. \tag{2}$$

The n roots of the denominator are given by

$$\frac{\sin\theta_r}{\sin\theta_0} = \cos\left[\frac{2r-1}{2n}\pi + j\frac{H}{n}\right] \qquad (r = 1, 2, \cdots, n) \tag{3}$$

where

$$H = \sinh^{-1} 1/h. \tag{4}$$

Defining

$$p = \coth\theta \tag{5}$$

and

$$\frac{1}{\sin\theta_0} = \cosh\frac{J}{n}, \tag{6}$$

the roots θ_r of (3) are then given by

$$p_r'^2 = 1 - \frac{\cosh^2\frac{J}{n}}{\cos^2\left[\frac{2r-1}{2n}\pi + j\frac{H}{n}\right]} \tag{7}$$

from which it is convenient to form the following real quantities:

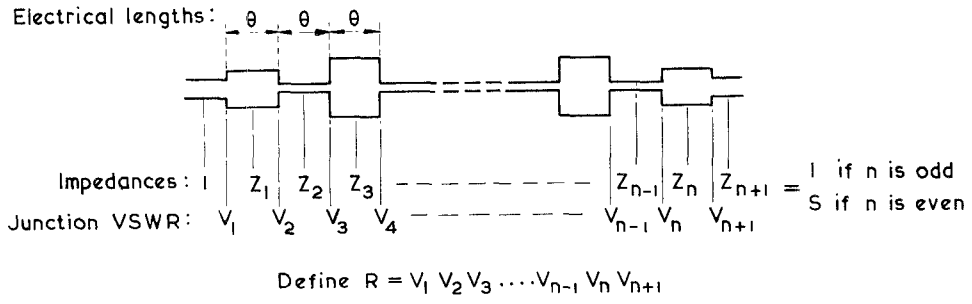
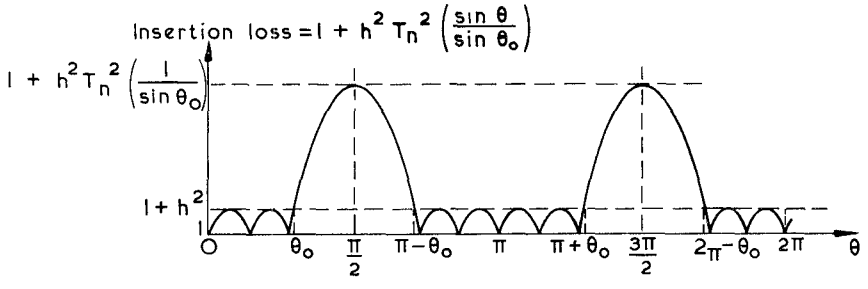


Fig. 1. Low-pass prototype filter.



$$\text{Maximum attenuation: } L = 10 \log_{10}\left[1 + h^2 T_n^2\left(\frac{1}{\sin\theta_0}\right)\right] = 10\log_{10}\left[\frac{(R+1)^2}{4R}\right] \text{ (db)}$$

$$\text{Bandwidth: } BW = \frac{4\theta_0}{\pi}$$

$$\text{Ripple VSWR: } S = 1 + 2h^2 + 2\sqrt{h^2 + h^4}$$

Fig. 2. Low-pass filter characteristic (case $n=5$).

$$|p_r'|^2 = \frac{\sqrt{\left(\cosh\frac{2(H+J)}{n} - \cos\frac{2r-1}{2n}\pi\right)\left(\cosh\frac{2(H-J)}{n} - \cos\frac{2r-1}{n}\pi\right)}}{\left(\cosh\frac{2H}{n} + \cos\frac{2r-1}{n}\pi\right)} \tag{8}$$

$$P_r' = p_r' + p_r'^* = \sqrt{2\left[1 - \frac{2\cosh^2\frac{J}{n}\left(\cosh\frac{2H}{n}\cos\frac{2r-1}{n}\pi + 1\right)}{\left(\cosh\frac{2H}{n} + \cos\frac{2r-1}{n}\pi\right)^2} + |p_r'|^2\right]}. \tag{9}$$

The n roots of the numerator of (2) may be expressed similarly in the form

$$|p_r|^2 = \frac{\cosh^2\frac{J}{n}}{\cos^2\frac{2r-1}{2n}\pi} - 1 \tag{10}$$

$$P_r = p_r + p_r^* = 0. \tag{11}$$

Now (2) may be written in terms of p as

$$|\Gamma(p)|^2 = K^2 \prod_{r=1}^{n} \frac{(p^2 - p_r^2)}{(p^2 - p_r'^2)} \tag{12}$$

where the zeros and poles p_r^2, $p_r'^2$ either are real or occur in complex conjugate pairs. For n even there are no real roots; for n odd, the root $p'^2_{(n+1)/2}$ is real. K is a constant to be determined later. The reflection coefficient $\Gamma(p)$ may be extracted from (12) provided no

poles exist in the right-half complex p plane, and the roots are chosen to be positive for convenience, leading to the expressions

$$\Gamma(p) = K_e \prod_{r=1}^{n/2} \frac{(p^2 + |p_r|^2)}{(p^2 + P_r'p + |p_r'|^2)} \qquad (n \text{ even}) \quad (13)$$

$$\Gamma(p) = \frac{K_0}{(p + p'_{(n+1)/2})} \sum_{r=1}^{1/2(n-1)} \frac{(p^2 + |p_r|^2)}{(p^2 + P_r'p + |p_r'|^2)} \qquad (n \text{ odd}). \quad (14)$$

The K values are obtained by comparing (13) and (14) with (2) after substituting $\sin^2\theta = 1/(p^2-1)$. For n even, (2) is of the form

$$|\Gamma|^2 = \frac{h^2[a_n \sin^n\theta + \cdots \pm 1]^2}{1 + h^2[a_n \sin^n\theta + \cdots \pm 1]^2} = \frac{h^2[a_n^2 \sin^{2n}\theta + \cdots + 1]}{1 + h^2[a_n^2 \sin^{2n}\theta + \cdots + 1]} = \frac{h^2}{1 + h^2}\left[\frac{p^{2n} + \cdots}{p^{2n} + \cdots}\right]$$

giving

$$K_e = \frac{h}{\sqrt{1 + h^2}} = \frac{1}{\cosh H}. \quad (15)$$

For n odd (2) is of the form

$$|\Gamma|^2 = \frac{h^2[a_n \sin^n\theta + \cdots \pm a_1 \sin\theta]^2}{1 + h^2[a_n \sin^n\theta + \cdots \pm a_1 \sin\theta]^2} = \frac{h^2[a_n^2 \sin^{2n}\theta + \cdots + a_1^2 \sin^2\theta]}{1 + h^2[a_n^2 \sin^{2n}\theta + \cdots + a_1^2 \sin^2\theta]} = \frac{h^2[a_n^2 + \cdots + a_1^2(p^2-1)^{n-1}]}{(p^2-1)^n + h^2[a_n^2 + \cdots + a_1^2(p^2-1)^{n-1}]}.$$

A comparison of this with $|\Gamma(p)|^2$ obtained from (14) shows that the coefficient of p^{2n} in the denominator of either expression is unity, so that it is necessary to compare only the respective numerators, and in fact only the coefficients of p^{2n-2} in the numerators, giving

$$K_0 = ha_1$$

The Chebyshev polynomial of odd degree $T_n(x)$ always has a lowest-degree term given by $\pm nx$, and since $x = \sin\theta/\sin\theta_0$ in (2), this leads to $a_1 = n/\sin\theta_0$, i.e.,

$$K_0 = \frac{nh}{\sin\theta_0} = \frac{n\cosh\frac{J}{n}}{\sinh H}. \quad (16)$$

Using (13) and (15) for n even, or (14) and (16) for n odd, the normalized input impedance to the LPF is derived from the formula

$$Z(p) = \frac{1 + \Gamma(p)}{1 - \Gamma(p)} = \frac{P_n(p)}{Q_n(p)} \quad (17)$$

where $P_n(p)$ and $Q_n(p)$ are positive real polynomials of the nth degree.

The transfer matrix of a uniform transmission line of impedance Z and electrical length θ is

$$\begin{bmatrix} \cos\theta & jZ\sin\theta \\ j\sin\theta/Z & \cos\theta \end{bmatrix}$$

which may be written in terms of p in the form

$$\frac{1}{\sqrt{p^2-1}}\begin{bmatrix} p & Z \\ 1/Z & p \end{bmatrix} \quad (18)$$

The cascade of n equal length sections has the transfer matrix

$$\frac{1}{(p^2-1)^{n/2}} \prod_{r=1}^{n} \begin{bmatrix} p & Z_r \\ 1/Z_r & p \end{bmatrix} = \frac{1}{(p^2-1)^{n/2}}\begin{bmatrix} A(p) & B(p) \\ C(p) & D(p) \end{bmatrix} \quad (19)$$

and the input impedance of the cascade is

$$Z(p) = \frac{A(p) + B(p)}{C(p) + D(p)} \quad (20)$$

where $A(p)$, $D(p)$ are even when n is even and odd when n is odd, and $B(p)$, $C(p)$ have the opposite relationship. This enables the overall transfer matrix of the LPF to be determined from (17). The matrix

$$\begin{bmatrix} A(p) & B(p) \\ C(p) & D(p) \end{bmatrix}$$

is broken down into its n constituent matrices by successive premultiplications by the inverse matrix

$$\begin{bmatrix} p & -Z_r \\ -1/Z_r & p \end{bmatrix},$$

and then at each stage, using the condition that all four elements of the resulting matrix must be divisible by (p^2-1). It is found that this process gives two expressions for Z_r, e.g., the first impedance is

$$Z_1 = \frac{\text{Sum of coefficients of } A(p)}{\text{Sum of coefficients of } C(p)} = \frac{\text{Sum of coefficients of } B(p)}{\text{Sum of coefficients of } D(p)} \quad (21)$$

A comparison of the two expressions enables a check on the accuracy to be made.

The impedances of the LPF are related by the conditions

$$Z_r Z_{n-r+1} = \begin{cases} 1 & (n \text{ odd}) \\ S & (n \text{ even}) \end{cases} \tag{22}$$

where S is the ripple VSWR, given in terms of h of (1) by

$$S = 1 + 2h^2 + 2\sqrt{h^2 + h^4} \tag{23}$$

In the case of n even, S is equal to the output impedance, as depicted in Fig. 1. Hence it is necessary to compute the impedances only as far as $r = (n+1)/2$ for n odd, and to $r = n/2$ for n even.

III. Considerations of Accuracy

In the synthesis of the LPF the overall transfer matrix is derived, and then broken down into its constituent matrices. This process requires great precision since at some stages in the synthesis two large numbers are subtracted and the result must be extremely accurate. Thus, errors accumulate in the synthesis procedure, being greatest for the last element value synthesized.

The entire synthesis procedure has been programmed for a computer, taking advantage of (21) to check the accuracy. The two expressions for Z_r are compared at each stage, and the result—taken to be the mean value—is not printed if they differ by more than a specified amount. Otherwise the mean value is printed to that number of decimal places justified by the value of the difference, subject to a maximum of three decimal places if $Z_r > 1$ and four decimal places if $Z_r < 1$. If the difference in impedance obtained from the two expressions of (21) is ΔZ, the result for an impedance Z is printed as shown in Table 1. It is not claimed that the result is always accurate to the number of decimal places printed because the errors in Z_r in the two expressions of (21) may be in the same direction, i.e., ΔZ is the difference of two inaccurate values, and could conceivably be zero even when the true error is considerable. In fact, it is almost certain that this effect could occur only for the last one or two values of impedance formed, since the next value would be highly inaccurate, and consequently would not be printed. There is evidence from the tables that when the last results formed are printed to an accuracy of two decimal places or less, then in many cases these are in fact less accurate than indicated. For example in Table 21,

$$\text{VSWR} = 1.10, \quad \text{BW} = 0.60, \quad Z_7 = 4.238,$$
$$Z_8 = 0.2585, \quad Z_9 = 4.2, \quad Z_{10} = 0.27,$$

that is,

$$Z_9 < Z_7 \text{ and } Z_{10} > Z_8,$$

whereas the reverse relationships ought to hold. This is because the junction VSWRs (the ratio of adjacent impedances) should increase monotonically towards the center of the filter,[1] with the possible exception of the first junction where there can be a "spike" for large bandwidths. In correcting errors it is useful to use the fact that when n is large the few central junction VSWR's are all nearly equal, or, alternatively, the fact that the impedances tend to repeat. In the example quoted the junction VSWR $Z_7/Z_8 = 16.4$; so, assuming

$$Z_9/Z_8 = Z_9/Z_{10} = Z_{11}/Z_{10} = 16.4,$$

it would be preferable to take

$$Z_9 = 4.24, \quad Z_{10} = 0.2585, \quad Z_{11} = 4.24.$$

This gives also a method for filling in many of the gaps in the tables, e.g., for Z_{11} in the case cited.

The result will be not quite perfect, but sufficiently good for any practical application. The errors occur only for extreme values [large number of elements n and small bandwidth (BW)]. To summarize, it should be noted that when the number of decimal places printed is less than the maximum (four for $Z < 1$, three for $Z > 1$) the accuracy of the computing process has begun to deteriorate. The printed values should then be used with caution, and may, indeed, require modification.

IV. Explanation of the Tables

The tabulated values in Tables 2–21 are of the characteristic impedances of the LPF for a given VSWR pass-band ripple level and BW. The (BW) is identical to the fractional BW of the quarter-wave transformer prototype w_q as defined by Young [3], i.e.,

$$\text{BW} = w_q = \frac{4\theta_0}{\pi} \tag{24}$$

where θ_0 is defined as shown in Fig. 2. Bandwidth is defined in this way to give consistency between the tables of this paper and those of Young [1]–[3].

The value L on the line beneath the BW value is the maximum attenuation in decibels exhibited by the LPF in its stop band when all sections are multiples of one quarter-wavelength. L is related to R, the ratio of the input to output impedances of the quarter-wave transformer prototype, or the product of the junction VSWR's, by the formula

$$L = 10 \log_{10} \frac{(R+1)^2}{4R} \tag{25}$$

As stated in Section II, it is necessary to print impedance values only up to the center of the filter because the remaining impedances are given by (22).

[1] This has never been proved formally, but may be considered to be true, since no case that violates it has been discovered.

Since the possible combinations of n, BW, and ripple level are so large, a restriction has been placed on the number of results for this paper. Presented in the cases $n=2$ to $n=8$ are ripple VSWRs of 1.01, 1.02, 1.05, 1.10, 1.20, 1.50, and 2.00. The range of BW given is that which should be most useful for the design of broad-band filters and transformers. The very low VSWR values of 1.01 and 1.02 should be extremely useful in the design of ultrabroadband transformers, or for narrow or wide-band filters of low ripple tolerance. The latter are frequently specified for communications systems, and since existing design methods not based on a distributed prototype were shown to be unsatisfactory [4], [8], the information given in the tables should prove to be of special value. For these types of components values of n up to 8 were thought to be sufficient for the very low VSWR values, coupled with extreme values for the bandwidth.

In the tables for $n=9$ to $n=21$ the VSWR ripple level commences at 1.05; extreme values of BW are not given. Bandwidth could not be chosen to be very small for large n because of the restriction imposed by the accuracy of the computer. However, narrow-band filters having a large number of cavities are rarely required. For narrow BWs it is known that approximate methods give very good results ([3], Section VIII).

In the design of direct coupled filters using the LPF prototype [3], [4] the junction VSWR, defined as the ratio of the two impedances bounding each junction, is a more useful parameter than the line impedance, but can easily be obtained from the tables. The reasons why the impedances are tabulated rather than the junction VSWRs are first, that the latter become very large in many cases and occupy more space, and secondly, that it is difficult to specify the accuracy because each junction VSWR (except the first) involves two derived impedances. Possibly a method of synthesis which extracts junction VSWR directly might overcome this difficulty.

The synthesis was programmed for the powerful "Atlas" computer. The total computing time for the twenty tables was less than one minute, and the printing time using a line printer was of the same order. The accuracy of computation was to 40 binary digits, i.e., to one part in 10^{12}. Originally the tables were more extensive than those presented here, and in order to give the information in a reasonable space they were reduced by removing certain values of the parameters, and recomposing the tables. These were then photographically reduced by a ratio of two to one. The results are legible but the process accounts for their imperfect reproduction.

V. Directory of the Tables

Table 1 gives the accuracy criteria for printing of the computed results.

Tables 2–21 give the step impedances of the LPF prototype, with the table number corresponding to the number of elements N. (In the text n has been used for N.)

The ranges of parameters tabulated are as follows:

Table No.	VSWR Values	$BW = W_q = \frac{4\theta_0}{\pi}$		
		Lower Value	Increment	Upper Value
2–6	1.01, 1.02	0.01 0.20 1.70	0.01 0.10 0.20	0.10 1.50 1.90
	1.05, 1.10, 1.20, 1.50, 2.00	0.10	0.10	1.00
7	1.01, 1.02	0.05 0.20	0.01 0.10	0.10 1.90
	1.05, 1.10, 1.20, 1.50, 2.00	0.10 1.40	0.10	1.20
8	1.01, 1.02	0.05 0.20	0.01 0.10	0.10 1.90
	1.05, 1.10, 1.20, 1.50, 2.00	0.20 1.40	0.10	1.20
9	1.05, 1.10, 1.20, 1.50, 2.00	0.20	0.10	1.40
10–12		0.30	0 10	1.40
13–14		0.40	0.10	1.40
15–16		0.50	0.10	1.40
17–21		0.60 1.00	0.10 0.20	0.80 1.40

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TABLE 1

ACCURACY CRITERIA FOR PRINTING OF COMPUTED RESULTS

Range of Z	Range of Z	No. of Decimal Places Printed
$Z<1$	$0<\Delta Z<0.0001$	4
	$0.0001<\Delta Z<0.001$	3
$Z<0.1$	$0.001<\Delta Z$	Not printed
$0.1<Z<1$	$0.001<\Delta Z<0.01$	2
	$0.01<\Delta Z$	Not printed
$Z>1$	$0<\Delta Z<0.001$	3
	$0.001<\Delta Z<0.01$	2
	$0.01<\Delta Z<0.03$	1
$1<Z<10$	$0.03<\Delta Z$	Not printed
$Z>10$	$0.03<\Delta Z<0.003Z$	0
	$0.003Z<\Delta Z$	Not printed

TABLE 2

STEP IMPEDANCES OF 2-ELEMENT FILTERS

N = 2 VSWR = 1.01

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	44.15	32.11	25.08	20.11	16.30	13.24	10.73	8.66	6.95	5.56	0.65	0.13	0.04
1	18.006	9.004	6.004	4.507	3.612	3.019	2.601	2.292	2.059	1.878	1.219	1.095	1.053

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.035	1.024	1.018	1.015	1.012	1.010	1.009	1.008	1.007	1.006	1.006	1.005	1.005

N = 2 VSWR = 1.02

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	50.13	38.09	31.05	26.04	22.20	19.06	16.42	14.17	12.22	10.53	2.15	0.51	0.17
1	25.465	12.732	8.489	6.368	5.096	4.250	3.647	3.198	2.850	2.575	1.449	1.195	1.109

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	0.07	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.070	1.049	1.037	1.029	1.024	1.020	1.017	1.015	1.014	1.013	1.012	1.011	1.010

N = 2 VSWR = 1.05

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	18.02	6.88	2.45	0.92	0.40	0.19	0.10	0.06	0.04	0.02
1	4.032	2.069	1.500	1.280	1.178	1.125	1.093	1.073	1.059	1.050

N = 2 VSWR = 1.10

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	23.79	11.99	5.91	2.80	1.35	0.69	0.38	0.22	0.14	0.09
1	5.694	2.865	1.963	1.563	1.363	1.253	1.188	1.147	1.119	1.100

N = 2 VSWR = 1.20

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	29.42	17.43	10.65	6.35	3.68	2.13	1.25	0.76	0.48	0.31
1	8.050	4.027	2.703	2.066	1.715	1.506	1.378	1.294	1.238	1.198

N = 2 VSWR = 1.50

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	36.41	24.35	17.33	12.45	8.85	6.19	4.26	2.91	2.00	1.38
1	12.726	6.356	4.235	3.181	2.561	2.162	1.893	1.706	1.574	1.479

N = 2 VSWR = 2.00

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	41.18	29.11	22.05	17.05	13.23	10.20	7.78	5.87	4.39	3.27
1	17.997	8.985	5.980	4.477	3.580	2.988	2.574	2.275	2.053	1.887

TABLE 3

STEP IMPEDANCES OF 4-ELEMENT FILTERS

N = 3 VSWR = 1.01

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	92.27	74.21	63.64	56.15	50.33	45.58	41.56	38.08	35.01	32.26	14.32	5.12	1.44
1	35.156	17.589	11.737	8.815	7.065	5.900	5.070	4.449	3.968	3.584	1.891	1.376	1.174
2	0.0151	0.0301	0.0453	0.0606	0.0760	0.0916	0.1074	0.1235	0.1399	0.1566	0.3471	0.5733	0.7631

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	0.41	0.14	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.092	1.054	1.035	1.025	1.018	1.014	1.011	1.009	1.008	1.007	1.006	1.005	1.005
2	0.8729	0.9296	0.9598	0.9767	0.9868	0.9930	0.9970	0.9997	1.001	1.003	1.004	1.005	1.005

N = 3 VSWR = 1.02

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	98.25	80.19	69.62	62.12	56.31	51.56	47.54	44.06	40.98	38.24	20.18	9.96	4.07
1	44.704	22.360	14.916	11.197	8.967	7.483	6.424	5.631	5.016	4.524	2.341	1.646	1.333
2	0.0122	0.0245	0.0367	0.0491	0.0615	0.0740	0.0866	0.0994	0.1123	0.1254	0.2691	0.4417	0.6252

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	1.45	0.52	0.21	0.09	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1	1.183	1.110	1.071	1.050	1.037	1.028	1.023	1.019	1.016	1.014	1.013	1.011	1.010
2	0.7731	0.8672	0.9221	0.9543	0.9739	0.9861	0.9941	0.9993	1.003	1.005	1.007	1.009	1.010

N = 3 VSWR = 1.05

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	46.07	27.97	17.41	10.18	5.32	2.50	1.13	0.52	0.25	0.13
1	6.229	3.172	2.175	1.695	1.427	1.270	1.179	1.126	1.092	1.071
2	0.0965	0.2109	0.3201	0.4561	0.5995	0.7286	0.8267	0.8937	0.9377	0.9684

N = 3 VSWR = 1.10

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	51.89	33.79	23.17	15.68	10.08	5.99	3.28	1.71	0.89	0.47
1	8.319	4.053	2.749	2.110	1.737	1.502	1.348	1.249	1.185	1.142
2	0.0818	0.1680	0.2626	0.3684	0.4853	0.6069	0.7208	0.8154	0.8866	0.9373

N = 3 VSWR = 1.20

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	57.53	38.43	28.80	21.2.	15.40	10.75	7.11	4.43	2.63	1.51
	10.446	5.256	3.540	2.691	2.188	1.860	1.633	1.473	1.360	1.281
	0.0725	0.1475	0.2275	0.3145	0.4097	0.5127	0.6198	0.7240	0.8171	0.8936

N = 3 VSWR = 1.50

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	64.52	46.42	35.79	28.20	22.28	17.44	13.37	9.94	7.12	4.89
1	15.159	7.601	5.090	3.841	3.095	2.601	2.251	1.992	1.795	1.644
2	0.0683	0.1380	0.2105	0.2870	0.3687	0.4564	0.5499	0.6480	0.7478	0.8447

N = 3 VSWR = 2.00

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	69.29	51.19	40.56	32.97	27.04	22.16	18.00	14.41	11.29	8.60
1	20.480	10.254	6.851	5.153	4.137	3.460	2.978	2.618	2.339	2.118
2	0.0720	0.1450	0.2201	0.2984	0.3807	0.4678	0.5602	0.6579	0.7599	0.8643

TABLE 4

Step Impedances of 4 Element Filters

N = 4 VSWR = 1.01

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	140.39	116.31	102.22	92.22	84.47	78.13	72.77	68.13	64.04	60.37	36.24	22.09	12.21
1	45.818	22.918	15.290	11.478	9.194	7.673	6.589	5.777	5.147	4.645	2.416	1.712	1.386
2	0.010	0.0201	0.0302	0.0403	0.0504	0.0606	0.0708	0.0811	0.0915	0.1019	0.2127	0.3405	0.4902

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	5.47	1.93	0.62	0.21	0.08	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1	1.211	1.117	1.068	1.042	1.028	1.020	1.015	1.012	1.009	1.008	1.007	1.006	1.005
2	0.6522	0.7919	0.8836	0.9354	0.9641	0.9803	0.9898	0.9956	0.9991	1.001	1.003	1.004	1.005

N = 4 VSWR = 1.02

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	146.37	122.29	108.20	98.20	90.45	84.11	78.75	74.11	70.01	66.35	42.21	28 04	17.99
1	55.616	27.816	18.553	13.924	11.148	9.300	7.981	6.993	6.226	5.613	2.884	2.007	1.591
2	0.0087	0.0173	0 0260	0.0347	0.0434	0.0522	0.0609	0.0698	0.0786	0.0875	0.1804	0.2839	0.4022

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	10.41	5.08	2.07	0.78	0.30	0.12	0.05	0.02	0.01	0.01	0.00	0.00	0.00
1	1.357	1.217	1.133	1.085	1.057	1.040	1.030	1.023	1.019	1.016	1.014	1.011	1.010
2	0.5359	0.6748	0.7948	0.8787	0.9306	0.9614	0.9799	0.9912	0.9983	1.003	1.006	1.009	1.010

N = 4 VSWR = 1.05

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	74.18	50.05	35.87	25.76	17.90	11.61	6.74	3.42	1.57	0.69
1	7.321	3.720	2.544	1.975	1.646	1.437	1.297	1.202	1.140	1.101
2	0.0732	0.1493	0.2310	0.3209	0.4212	0.5319	0.6483	0.7582	0.8473	0.9105

N = 4 VSWR = 1.10

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	80.00	55.87	41.69	31.57	23.67	17.20	11.82	7.46	4.24	2.19
1	9.086	4.591	3.112	2.388	1.964	1.690	1.500	1.365	1.267	1.197
2	0.0658	0.1334	0.2045	0.2809	0.3643	0.4557	0.5550	0.6589	0.7595	0.8465

N = 4 VSWR = 1.20

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	85.64	61.51	47.33	37.21	29.30	22.78	17.25	12.50	8.50	5.33
1	11.472	5.773	3.890	2.959	2.410	2.050	1.799	1.614	1.474	1.368
2	0.0613	0.1239	0.1887	0.2572	0.3303	0.4091	0.4944	0.5859	0.6817	0.7766

N = 4 VSWR = 1.50

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	92.63	68.50	54.32	44.20	36.29	29.75	24.17	19.29	14.97	11.15
1	16.125	8.088	5.420	4.094	3.305	2.784	2.414	2.140	1.929	1.762
2	0.0610	0.1227	0.1860	0.2516	0.3203	0.3929	0.4702	0.5526	0.6403	0.7326

N = 4 VSWR = 2.00

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	97.41	73.27	59.09	48.97	41.06	34.52	28.93	24.02	19.64	15.70
1	21.426	10.731	7.174	5.402	4.343	3.640	3.140	2.767	2.478	2.247
2	0.0661	0.1329	0.2010	0.2710	0.3436	0.4195	0.4994	0.5839	0.6733	0.7680

TABLE 5

Step Impedances of 5-Element Filters

N = 5 VSWR = 1.01

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	188.51	158.41	140.80	128.30	118.61	110.69	103.99	98.19	93.07	88.49	58.32	40.60	27.95
1	52.182	26.100	17.410	13.068	10.465	8.731	7.495	6.569	5.850	5.276	2.726	1.913	1.532
2	0.0084	0.0169	0.0253	0.0338	0.0423	0.0508	0.0593	0.0679	0.0765	0.0852	0.1752	0.2743	0.3847
3				35	27.8	23.15	19.83	17.338	15.398	13.845	6.810	4.404	3.149

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	18.12	10.31	4.69	1.68	0.54	0.18	0.06	0.02	0.01	0.00	0.00	0.00	0.00
1	1.322	1.196	1.118	1.070	1.043	1.028	1.020	1.014	1.011	1.009	1.007	1.006	1.005
2	0.5067	0.6365	0.7617	0.8607	0.9235	0.9590	0.9786	0.9896	0.9960	0.9997	1.002	1.004	1.005
3	2.356	1.811	1.445	1.229	1.119	1.065	1.038	1.023	1.015	1.011	1.008	1.006	1.005

N = 5 VSWR = 1.02

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	194.49	164.38	146.77	134.28	124.58	116.66	109.97	104.16	99.05	94.47	64.29	46.57	33.92
1	61.838	30.927	20.626	15.478	12.392	10.335	8.868	7.769	6.915	6.233	3.190	2.208	1.740
2	0.0075	0.0150	0.0225	0.0300	0.0375	0.0451	0.0527	0.0602	0.0679	0.0755	0.1543	0.2391	0.3322
3					31.13	25.92	22.21	19.425	17.255	15.518	7.666	4.999	3.623

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	24.04	15.97	9.39	4.58	1.83	0.66	0.24	0.09	0.04	0.01	0.01	0.00	0.00
1	1.475	1.311	1.204	1.132	1.085	1.057	1.040	1.029	1.022	1.018	1.015	1.011	1.010
2	0.4345	0.5453	0.6610	0.7717	0.8614	0.9218	0.9582	0.9795	0.9920	0.9995	1.004	1.008	1.010
3	2.761	2.161	1.727	1.423	1.234	1.130	1.076	1.047	1.031	1.022	1.016	1.012	1.010

N = 5 VSWR = 1.05

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	102.30	72.13	54.41	41.76	31.86	23.71	16.79	10.92	6.22	3.01
1	7.909	4.012	2.739	2.120	1.763	1.536	1.381	1.272	1.193	1.136
2	0.0656	0.1332	0.2043	0.2807	0.3632	0.4525	0.5483	0.6485	0.7481	0.8371
3	17.944	8.899	5.847	4.289	3.326	2.659	2.165	1.789	1.507	1.310

N = 5 VSWR = 1.10

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	108.12	77.95	60.23	47.57	37.68	29.51	22.54	16.47	11.20	6.83
1	9.640	4.868	3.297	2.528	2.077	1.786	1.585	1.440	1.332	1.258
2	0.0604	0.1222	0.1864	0.2543	0.3267	0.4043	0.4873	0.5757	0.6679	0.7602
3	20.82	9.948	6.561	4.842	3.787	3.063	2.528	2.115	1.789	1.536

N = 5 VSWR = 1.20

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	113.76	83.59	65.87	53.22	43.32	35.15	28.16	22.04	16.59	11.77
1	11.987	6.032	4.063	3.091	2.517	2.142	1.880	1.689	1.543	1.430
2	0.0576	0.1161	0.1763	0.2392	0.3054	0.3756	0.4502	0.5294	0.6133	0.7007
3	22.49	11.194	7.402	5.485	4.316	3.519	2.934	2.482	2.122	1.830

N = 5 VSWR = 1.50

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	120.75	90.58	72.86	60.21	50.31	42.14	35.15	29.01	23.50	18.52
1	16.594	8.324	5.579	4.216	3.404	2.869	2.490	2.210	1.995	1.825
2	0.0585	0.1176	0.1779	0.2402	0.3048	0.3724	0.4435	0.5184	0.5974	0.6807
3	27.1	13.489	8.940	6.647	5.256	4.314	3.628	3.101	2.681	2.338

N = 5 VSWR = 2.00

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	125.52	95.35	77.63	64.98	55.08	46.91	39.92	33.77	28.26	23.25
1	21.878	10.959	7.328	5.510	4.439	3.722	3.214	2.835	2.542	2.309
2	0.0642	0.1289	0.1947	0.2621	0.3316	0.4038	0.4791	0.5580	0.4409	0.7280
3	32.5	16.190	10.741	7.998	6.338	5.217	4.404	3.783	3.289	2.885

TABLE 6

Step Impedances of 6-Element Filters

N = 6 VSWR = 1.01

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	236.63	200.50	179.37	164.38	152.75	143.24	135.20	128.24	122.10	116.60	80.40	59.13	43.95
1	56.131	28.074	18.725	14.054	11.253	9.385	8.057	7.061	6.287	5.669	2.918	2 037	1.622
2	0.0077	0.0154	0.0231	0.0309	0.0386	0.0464	0.0541	0.0620	0.0698	0.0777	0.1590	0.2469	0 3431
3				40	32	26.68	22.86	19.991	17.760	15.973	7.902	5.169	3.765

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	32.08	22.30	14.05	7.38	2.95	0.94	0.28	0.09	0.03	0.01	0.00	0.00	0.00
1	1.391	1.251	1.162	1.103	1.064	1.040	1.026	1.018	1.013	1.010	1.008	1.006	1.005
2	0.4473	0.5573	0.6689	0.7752	0.8647	0.9262	0.9618	0.9812	0.9918	0.9977	1.001	1.004	1.005
3	2.889	2.277	1.824	1.487	1.260	1.132	1 068	1.037	1.022	1.014	1.010	1.006	1.005

N = 6 VSWR = 1.02

BW	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40
L(DB)	242.61	206.48	185.35	170.35	158.72	149.22	141.18	134.22	128.08	122.58	86.38	65.11	49.93
1	65.603	32 809	21.880	16.419	13.144	10.962	9.405	8.238	7.332	6.608	3.376	2.329	1.828
2	0.0070	0.0139	0.0209	0.0279	0.0349	0.0419	0.0489	0.0559	0.0630	0.0701	0.1426	0.2199	0.3035
3					35.0	29.2	25.00	21.87	19.43	17.478	8.668	5.695	4.178

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.70	1.90
L(DB)	38.05	28.26	19.90	12.72	6.86	2.92	1.02	0.33	0.11	0.04	0.01	0.00	0.00
1	1.544	1.368	1.251	1.172	1.116	1.077	1.051	1.036	1.026	1.020	1.016	1.012	1.010
2	0.3937	0.4899	0.5902	0.6913	0.7875	0.8694	0.9278	0.9634	0.9838	0.9954	1.002	1.008	1.010
3	3.239	2.589	2.105	1.732	1.448	1.252	1.136	1.075	1.044	1.028	1.019	1.012	1.010

N = 6 VSWR = 1.05

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	130.41	94.21	72.94	57.76	45.89	36.08	27.70	20.35	13.88	8.35
1	8.254	4.184	2.853	2.205	1.830	1.591	1.430	1.315	1.231	1.168
2	0.0621	0.1258	0.1925	0.2633	0.3391	0.4198	0.5052	0.5941	0.6845	0.7733
3	19.622	9.753	6.436	4.753	3.722	3.014	2.491	2.085	1.760	1.502

N = 6 VSWR = 1.10

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	136.23	100.03	78.76	63.58	51.71	41.90	33.51	26.14	19.56	13.67
1	9.959	5.127	3.403	2.617	2.141	1.840	1.632	1.482	1.371	1.285
2	0.0580	0.1170	0.1783	0.2425	0.3105	0.3826	0.4589	0.5390	0.6221	0.7070
3	21.46	10.680	7.063	5.245	4.120	3.361	2.803	2.371	2.024	1.740

N = 6 VSWR = 1.20

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	141.87	105.67	84.40	69.22	57.35	47.55	39.15	31.78	25.17	19.17
1	12.279	6.178	4.161	3.165	2.577	2.193	1.925	1.729	1.581	1.466
2	0.0558	0.1124	0.1706	0.2311	0.2944	0.3610	0.4313	0.5051	0.5824	0.6625
3	23.701	11.807	7.821	5.812	4.591	3.763	3.159	2.694	2.321	2.015

N = 6 VSWR = 1.50

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	148.86	112.66	91.39	76.21	64.34	54.53	46.14	38.76	32.15	26.12
1	16.856	8.455	5.667	4.282	3.459	2.915	2.531	2.248	2.030	1.859
2	0.0573	0.1152	0.1742	0.2349	0.2978	0.3633	0.4318	0.5034	0.5785	0.6568
3	28.0	13.973	9.270	6.903	5.470	4.503	3.801	3.265	2.837	2.487

N = 6 VSWR = 2.00

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
L(DB)	153.63	117.43	96.16	80.98	69.11	59.31	50.91	43.54	36.92	30.89
1	22.128	11.085	7.413	5.583	4.491	3.767	3.254	2.872	2.577	2.343
2	0.0632	0.1270	0.1917	0.2579	0.3261	0.3967	0.4701	0.5466	0.6265	0.7099
3	33	16.613	11.029	8.222	6.525	5.382	4.555	3.924	3.424	3.015

TABLE 7

STEP IMPEDANCES OF 7-ELEMENT FILTERS

N = 7 VSWR = 1.01

BW	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40	0.50	0.60	0.70
L(DB)	186.88	175.79	166.42	158.29	151.13	144.72	102.48	77.67	59.96	46.10	34.67	24.89
1	11.767	9.816	8.424	7.381	6.571	5.925	3.044	2.118	1.680	1.436	1.287	1.191
2	0.0366	0.0440	0.0513	0.0587	0.0662	0.0736	0.1503	0.2325	0.3217	0.4177	0.5184	0.6203
3	34	28.73	24.61	21.53	19.127	17.205	8.530	5.601	4.106	3.182	2.544	2.072
4				0.044	0.050	0.056	0.1122	0.1702	0.2311	0.2963	0.3684	0.4512

BW	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90
L(DB)	16.37	9.11	3.83	1.19	0.33	0.09	0.03	0.01	0.00	0.00	0.00	0.00
1	1.127	1.083	1.053	1.034	1.022	1.015	1.011	1.009	1.007	1.006	1.005	1.005
2	0.7190	0.8096	0.8855	0.9388	0.9698	0.9863	0.9951	0.9998	1.002	1.004	1.005	1.005
3	1.711	1.434	1.237	1.119	1.060	1.031	1.018	1.011	1.008	1.006	1.005	1.005
4	0.5495	0.6659	0.7891	0.8880	0.9466	0.9765	0.9911	0.9983	1.002	1.004	1.004	1.005

N = 7 VSWR = 1.02

BW	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40	0.50	0.60	0.70
L(DB)	192.86	181.77	172.40	164.27	157.11	150.69	108.46	83.65	65.93	52.08	40.64	30.86
1	13.627	11.364	9.749	8.540	7.600	6.849	3.495	2.407	1.885	1.588	1.403	1.281
2	0.0334	0.0401	0.0468	0.0536	0.0603	0.0671	0.1364	0.2097	0.2884	0.3729	0.4624	0.5550
3	37	31.00	26.56	23.24	20.646	18.574	9.224	6.077	4.477	3.494	2.819	2.320
4				0.042	0.047	0.053	0.1056	0.1599	0.2162	0.2756	0.3398	0.4111

BW	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90
L(DB)	22.27	14.67	8.20	3.52	1.17	0.34	0.10	0.03	0.01	0.00	0.00	0.00
1	1.197	1.138	1.095	1.065	1.044	1.031	1.022	1.017	1.014	1.012	1.011	1.010
2	0.6481	0.7383	0.8217	0.8922	0.9427	0.9733	0.9903	0.9996	1.005	1.007	1.009	1.010
3	1.935	1.631	1.394	1.222	1.118	1.063	1.036	1.023	1.016	1.013	1.011	1.010
4	0.4929	0.5888	0.6994	0.8121	0.9009	0.9544	0.9825	0.9966	1.004	1.007	1.009	1.010

N = 7 VSWR = 1.05

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	158.53	116.29	91.48	73.77	59.91	48.48	38.69	30.08	22.38	15.44	9.34	4.58	0.58
1	8.471	4.292	2.924	2.258	1.872	1.626	1.459	1.341	1.255	1.190	1.141	1.103	1.056
2	0.0602	0.1218	0.1861	0.2541	0.3263	0.4030	0.4835	0.5667	0.6509	0.7340	0.8133	0.8842	0.9771
3	20.521	10.209	6.747	4.995	3.925	3.196	2.660	2.247	1.916	1.647	1.430	1.264	1.089
4	0.0494	0.0992	0.1499	0.2019	0.2561	0.3133	0.3748	0.4426	0.5192	0.6071	0.7070	0.8111	0.9589

N = 7 VSWR = 1.10

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	164.35	122.11	97.30	79.59	65.73	54.30	44.50	35.90	28.18	21.17	14.77	9.11	1.88
1	10.158	5.126	3.469	2.656	2.180	1.873	1.660	1.508	1.394	1.307	1.239	1.186	1.109
2	0.0566	0.1142	0.1738	0.2361	0.3018	0.3712	0.4442	0.5204	0.5989	0.6785	0.7577	0.8343	0.9604
3	22.21	11.059	7.321	5.435	4.288	3.509	2.939	2.501	2.151	1.864	1.626	1.430	1.173
4		0.0966	0.1458	0.1961	0.2480	0.3021	0.3594	0.4211	0.4889	0.5649	0.6511	0.7470	0.9291

N = 7 VSWR = 1.20

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	169.99	127.75	102.94	85.23	71.37	59.94	50.15	41.54	33.82	26.79	20.31	14.35	4.75
1	12.459	6.268	4.221	3.210	2.613	2.223	1.951	1.753	1.603	1.487	1.394	1.320	1.207
2	0.0548	0.1104	0.1675	0.2266	0.2884	0.3533	0.4213	0.4925	0.5666	0.6428	0.7205	0.7984	0.9455
3	24.31	12.116	8.032	5.974	4.726	3.882	3.268	2.797	2.422	2.115	1.857	1.640	1.316
4	0.049	0.0969	0.1460	0.1961	0.2474	0.3006	0.3562	0.4151	0.4784	0.5477	0.6247	0.7108	0.9002

N = 7 VSWR = 1.50

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	176.98	134.74	109.93	92.22	78.36	66.93	57.14	48.53	40.81	33.77	27.27	21.21	10.38
1	17.016	8.536	5.721	4.323	3.492	2.943	2.556	2.270	2.051	1.879	1.740	1.626	1.449
2	0.0567	0.1139	0.1722	0.2320	0.2940	0.3583	0.4255	0.4956	0.5686	0.6445	0.7229	0.8035	0.9675
3	28.5	14.211	9.431	7.028	5.574	4.594	3.884	3.342	2.913	2.561	2.267	2.017	1.620
4		0.1039	0.1566	0.2100	0.2645	0.3205	0.3785	0.4391	0.5030	0.5713	0.6453	0.7264	0.9124

N = 7 VSWR = 2.00

BW	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	181.75	139.51	114.70	96.99	83.14	71.70	61.91	53.30	45.58	38.54	32.03	25.96	14.88
1	22.280	11.161	7.464	5.622	4.523	3.794	3.278	2.893	2.597	2.362	2.172	2.014	1.767
2	0.0627	0.1259	0.1901	0.2557	0.3231	0.3929	0.4653	0.5405	0.6189	0.7004	0.7850	0.8725	1.055
3	34	16.819	11.168	8.329	6.613	5.459	4.625	3.990	3.488	3.079	2.736	2.445	1.977
4		0.118	0.1770	0.2373	0.2986	0.3614	0.4261	0.4932	0.5635	0.6378	0.7171	0.8029	0.9979

TABLE 8

Step Impedances of 8-Element Filters

N = 8 VSWR = 1.01

BW	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40	0.50	0.60	0.70
L(DB)	221.02	208.35	197.63	188.35	180.16	172.83	130.54	102.18	81.94	66.11	53.04	41.85
1	12.118	10.108	8.674	7.600	6.766	6.099	3.575	2.459	1.923	1.618	1.427	1.301
2	0.0354	0.0425	0.0496	0.0568	0.0640	0.0712	0.1326	0.2036	0.2794	0.3606	0.4463	0.5349
3	36	29.999	25.71	22.484	19.978	17.972	9.563	6.308	4.657	3.645	2.953	2.445
4		0.0313		0.042	0.0470	0.052	0.0999	0.1511	0.2037	0.2586	0.3169	0.3800

BW	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90
L(DB)	26.04	17.29	9.66	3.96	1.14	0.28	0.07	0.02	0.00	0.00	0.00	0.00
1	1.143	1.097	1.065	1.042	1.027	1.018	1.013	1.009	1.007	1.006	1.006	1.005
2	0.6867	0.7737	0.8502	0.9124	0.9551	0.9794	0.9919	0.9984	1.002	1.004	1.004	1.005
3	1.851	1.565	1.345	1.187	1.092	1.045	1.023	1.013	1.009	1.007	1.006	1.005
4	0.4879	0.5828	0.6945	0.8126	0.9059	0.9587	0.9839	0.9955	1.001	1.003	1.004	1.005

N = 8 VSWR = 1.02

BW	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.30	0.40	0.50	0.60	0.70
L(DB)	227.00	214.33	203.61	194.33	186.14	178.81	124.56	96.20	75.96	60.13	47.06	35.87
1	13.953	11.636	9.982	8.743	7.780	7.011	3.129	2.174	1.720	1.466	1.311	1.210
2	0.0325	0.0390	0.0456	0.0521	0.0587	0.0653	0.1451	0.2240	0.3091	0.4004	0.4960	0.5928
3	39	32.1	27.517	24.07	21.389	19.243	8.919	5.868	4.315	3.358	2.702	2.219
4			0.0348	0.040	0.045	0.050	0.1049	0.1588	0.2147	0.2736	0.3371	0.4074

BW	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90
L(DB)	32.01	23.21	15.27	8.38	3.40	1.01	0.26	0.07	0.02	0.00	0.00	0.00
1	1.214	1.153	1.109	1.076	1.052	1.035	1.025	1.019	1.015	1.012	1.011	1.010
2	0.6237	0.7097	0.7898	0.8613	0.9199	0.9606	0.9842	0.9968	1.004	1.007	1.009	1.010
3	2.054	1.746	1.502	1.310	1.172	1.089	1.047	1.027	1.018	1.013	1.011	1.010
4	0.4501	0.5304	0.6242	0.7318	0.8403	0.9224	0.9686	0.9912	1.002	1.007	1.009	1.010

N = 8 VSWR = 1.05

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	138.37	110.01	89.77	73.94	60.87	49.68	39.84	31.02	22.99	15.65	9.14	1.39
1	4.364	2.972	2.293	1.900	1.649	1.478	1.358	1.270	1.204	1.154	1.115	1.062
2	0.1194	0.1822	0.2485	0.3187	0.3930	0.4709	0.5510	0.6319	0.7113	0.7872	0.8575	0.9639
3	10.480	6.931	5.137	4.044	3.301	2.757	2.338	2.006	1.736	1.515	1.337	1.114
4	0.0953	0.1438	0.1934	0.2446	0.2981	0.3549	0.4162	0.4838	0.5601	0.6477	0.7468	0.9297

N = 8 VSWR = 1.10

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	144.19	115.83	95.59	79.76	66.69	55.50	45.66	36.84	28.79	21.38	14.55	3.87
1	5.192	3.513	2.689	2.206	1.894	1.679	1.524	1.409	1.321	1.253	1.199	1.119
2	0.1125	0.1711	0.2322	0.2966	0.3643	0.4355	0.5095	0.5855	0.6622	0.7381	0.8116	0.9415
3	11.281	7.472	5.551	4.384	3.593	3.017	2.575	2.222	1.935	1.697	1.499	1.212
4	0.0937	0.1413	0.1897	0.2395	0.2911	0.3451	0.4026	0.4646	0.5329	0.6096	0.6965	0.8883

N = 8 VSWR = 1.20

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	149.83	121.48	101.23	85.40	72.33	61.14	51.30	42.48	34.43	27.00	20.08	7.97
1	6.327	4.261	3.240	2.637	2.243	1.969	1.768	1.617	1.500	1.407	1.333	1.220
2	0.1092	0.1656	0.2239	0.2848	0.3486	0.4154	0.4851	0.5573	0.6315	0.7065	0.7815	0.9252
3	12.295	8.153	6.068	4.804	3.950	3.329	2.855	2.478	2.170	1.913	1.697	1.362
4	0.0946	0.1426	0.1914	0.2412	0.2925	0.3459	0.4019	0.4614	0.5257	0.5962	0.6748	0.8579

N = 8 VSWR = 1.50

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	156.82	128.47	108.22	92.39	79.32	68.13	58.29	49.47	41.42	33.99	27.04	14.37
1	8.588	5.757	4.350	3.513	2.961	2.572	2.285	2.064	1.891	1.752	1.638	1.463
2	0.1130	0.1709	0.2303	0.2916	0.3553	0.4217	0.4908	0.5627	0.6372	0.7139	0.7923	0.9510
3	14.347	9.523	7.098	5.632	4.644	3.930	3.385	2.954	2.602	2.309	2.060	1.663
4	0.102	0.1542	0.2067	0.2602	0.3150	0.3715	0.4302	0.4917	0.5569	0.6269	0.7031	0.8791

N = 8 VSWR = 2.00

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.40
L(DB)	161.59	133.24	112.99	97.16	84.09	72.90	63.06	54.24	46.19	38.76	31.81	19.04
1	11.211	7.497	5.648	4.544	3.812	3.293	2.907	2.610	2.374	2.184	2.026	1.781
2	0.1252	0.1890	0.2543	0.3213	0.3905	0.4623	0.5369	0.6144	0.6948	0.7780	0.8638	1.041
3	16.935	11.247	8.390	6.663	5.502	4.664	4.026	3.523	3.113	2.771	2.481	2.015
4	0.116	0.1751	0.2346	0.2950	0.3569	0.4204	0.4861	0.5545	0.6263	0.7026	0.7845	0.9706

TABLE 9

STEP IMPEDANCES OF 9-ELEMENT FILTERS

N = 9 VSWR = 1.05

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	160.45	126.55	105.78	87.97	73.26	60.67	49.61	39.68	30.63	22.28	14.59	7.83	3.02
1	4.415	3.005	2.318	1.920	1.665	1.492	1.369	1.280	1.213	1.163	1.123	1.092	1.068
2	0.1179	0.1496	0.2448	0.3136	0.3866	0.4627	0.5410	0.6199	0.6972	0.771	0.8392	0.9002	0.9505
3	10.654	7.050	5.229	4.121	3.367	2.817	2.395	2.061	1.790	1.569	1.390	1.246	1.142
4	0.0931	0.1404	0.1887	0.2384	0.2901	0.3445	0.4026	0.4658	0.5359	0.6149	0.7046	0.8032	0.8972
5		7.59	5.650	4.476	3.684	3.108	2.665	2.309	2.011	1.753	1.526	1.330	1.181

N = 9 VSWR = 1.10

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	166.27	134.37	111.60	93.79	79.08	66.49	55.43	45.56	36.45	28.06	20.30	13.09	6.84
1	5.237	3.543	2.712	2.225	1.909	1.692	1.535	1.419	1.330	1.262	1.207	1.163	1.127
2	0.1114	0.1693	0.2297	0.2931	0.3599	0.4298	0.5025	0.5775	0.6520	0.7260	0.7973	0.8645	0.9256
3	11.423	7.569	5.626	4.446	3.647	3.065	2.629	2.286	1.979	1.741	1.543	1.379	1.248
4	0.0921	0.1387	0.1862	0.2349	0.2852	0.3376	0.3929	0.4521	0.5164	0.5875	0.6672	0.7566	0.8523
5		8.02	5.977	4.742	3.910	3.307	2.844	2.478	2.174	1.913	1.684	1.480	1.306

N = 9 VSWR = 1.20

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	171.91	140.01	117.24	99.43	84.72	72.13	61.07	51.14	42.09	33.72	25.91	18.57	11.77
1	6.368	4.268	3.261	2.654	2.257	1.981	1.779	1.627	1.509	1.416	1.341	1.280	1.229
2	0.1064	0.1643	0.2222	0.2825	0.3455	0.4115	0.4812	0.5514	0.6242	0.6978	0.7709	0.8423	0.9107
3	12.489	8.230	6.127	4.852	3.992	3.368	2.891	2.513	2.204	1.948	1.732	1.550	1.397
4	0.0934	0.1407	0.1888	0.2378	0.2882	0.3404	0.3949	0.4525	0.5142	0.5812	0.6549	0.7369	0.8275
5		8.60	6.414	5.094	4.206	3.564	3.076	2.688	2.369	2.099	1.863	1.654	1.468

N = 9 VSWR = 1.50

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	176.90	147.00	124.23	106.42	91.71	79.12	68.06	58.13	49.08	40.71	32.89	25.51	18.52
1	8.625	5.781	4.368	3.528	2.974	2.583	2.294	2.074	1.900	1.761	1.647	1.552	1.472
2	0.1125	0.1700	0.2291	0.2901	0.3534	0.4192	0.4877	0.5589	0.6326	0.7082	0.7852	0.8629	0.9402
3	14.432	9.581	7.143	5.669	4.676	3.958	3.445	2.978	2.627	2.334	2.086	1.873	1.691
4	0.101	0.1529	0.2049	0.2578	0.3120	0.3677	0.4254	0.4858	0.5494	0.6172	0.6904	0.7703	0.8582
5		9.9	7.365	5.855	4.840	4.100	3.553	3.115	2.757	2.456	2.198	1.970	1.766

N = 9 VSWR = 2.00

BW	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	183.67	151.77	129.00	111.19	96.48	83.90	72.83	62.90	53.85	45.48	37.66	30.28	23.25
1	10.240	7.521	5.665	4.558	3.824	3.304	2.917	2.619	2.383	2.192	2.034	1.903	1.790
2	0.1248	0.1884	0.2533	0.3201	0.3890	0.4604	0.5344	0.6114	0.6911	0.7736	0.8583	0.9448	1.032
3	17.006	11.297	8.427	6.695	5.529	4.688	4.049	3.544	3.134	2.792	2.503	2.255	2.040
4	0.1116	0.1740	0.2331	0.2931	0.3544	0.4173	0.4822	0.5497	0.6203	0.6950	0.7746	0.8606	0.9541
5		11.5	8.619	6.855	5.671	4.818	4.171	3.661	3.247	2.900	2.604	2.345	2.114

TABLE 10

STEP IMPEDANCES OF 10-ELEMENT FILTERS]

N = 10 VSWR = 1.05

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	147.09	121.78	101.99	85.65	71.67	59.37	48.74	38.25	28.99	20.33	12.35	5.65
1	3.929	2.336	1.934	1.676	1.502	1.378	1.287	1.220	1.169	1.129	1.098	1.073
2	0.1779	0.2423	0.3103	0.3421	0.4571	0.5342	0.6118	0.6878	0.7602	0.8271	0.8870	0.9385
3	7.731	5.292	4.373	3.813	2.859	2.434	2.098	1.826	1.605	1.425	1.281	1.169
4	0.1383	0.1858	0.2346	0.2652	0.3382	0.3946	0.4554	0.5220	0.5960	0.6790	0.7711	0.8666
5	7.755	5.778	4.582	3.776	3.192	2.744	2.387	2.090	1.834	1.608	1.406	1.236

N = 10 VSWR = 1.10

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	152.91	127.60	107.81	91.47	77.49	65.19	54.16	44.10	34.80	26.12	17.97	10.49
1	3.565	2.728	2.238	1.920	1.711	1.543	1.426	1.337	1.268	1.213	1.170	1.134
2	0.1680	0.2279	0.2909	0.3568	0.4268	0.4977	0.5712	0.6451	0.7179	0.7879	0.8535	0.9136
3	7.634	5.676	4.487	3.683	3.098	2.651	2.296	2.007	1.769	1.572	1.409	1.276
4	0.1372	0.1841	0.2321	0.2816	0.3331	0.3872	0.4447	0.5068	0.5748	0.6500	0.7336	0.8250
5	8.15	6.080	4.826	3.983	3.373	2.909	2.539	2.235	1.976	1.749	1.545	1.364

N = 10 VSWR = 1.20

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	158.55	133.25	113.46	97.12	83.13	70.83	59.80	49.74	40.45	31.76	23.57	15.84
1	4.304	3.275	2.666	2.267	1.989	1.787	1.634	1.515	1.422	1.347	1.286	1.235
2	0.1634	0.2209	0.2809	0.3434	0.4088	0.4769	0.5473	0.6193	0.6919	0.7639	0.8339	0.9006
3	8.282	6.167	4.885	4.021	3.394	2.915	2.535	2.226	1.970	1.755	1.574	1.422
4	0.1396	0.1872	0.2357	0.2855	0.3370	0.3907	0.4473	0.5075	0.5724	0.6432	0.7212	0.8072
5	8.71	6.496	5.151	4.264	3.617	3.124	2.735	2.416	2.147	1.914	1.706	1.519

N = 10 VSWR = 1.50

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	165.54	140.26	120.44	104.11	90.12	77.82	66.79	56.73	47.44	38.74	30.54	22.74
1	5.798	4.382	3.539	2.983	2.591	2.302	2.088	1.906	1.766	1.653	1.558	1.478
2	0.1695	0.2283	0.2890	0.3520	0.4175	0.4856	0.5563	0.6294	0.7043	0.7805	0.8570	0.9329
3	9.620	7.173	5.693	4.697	3.977	3.429	2.996	2.644	2.350	2.103	1.891	1.710
4	0.1521	0.2038	0.2563	0.3101	0.3654	0.4226	0.4822	0.5449	0.6115	0.6830	0.7604	0.8450
5	10.0	7.495	5.904	4.883	4.147	3.589	3.149	2.791	2.491	2.234	2.008	1.806

N = 10 VSWR = 2.00

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	170.31	145.01	125.22	108.88	94.89	82.59	71.56	61.59	52.21	43.52	35.31	27.49
1	7.537	5.678	4.568	3.833	3.311	2.924	2.625	2.389	2.198	2.040	1.908	1.797
2	0.1879	0.2527	0.3192	0.3879	0.4590	0.5328	0.6093	0.6886	0.7705	0.8545	0.9401	1.027
3	11.330	8.453	6.716	5.547	4.714	4.064	3.558	3.148	2.806	2.517	2.270	2.056
4	0.1733	0.2321	0.2919	0.3529	0.4154	0.4799	0.5468	0.6167	0.6904	0.7688	0.8529	0.9439
5	11.61	8.670	6.897	5.707	4.851	4.202	3.691	3.276	2.929	2.634	2.376	2.147

TABLE 11

STEP IMPEDANCES OF 11-ELEMENT FILTERS

N = 11 VSWR = 1.05

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	165.62	137.79	116.02	98.05	82.66	69.14	57.00	45.94	35.71	26.16	17.20	9.09
1	3.047	2.349	1.944	1.685	1.509	1.384	1.293	1.225	1.173	1.134	1.102	1.078
2	0.1766	0.2404	0.3079	0.3789	0.4531	0.5203	0.6060	0.6812	0.7527	0.8187	0.8777	0.9289
3	7.189	5.336	4.210	3.445	2.888	2.461	2.123	1.851	1.630	1.450	1.305	1.191
4	0.1370	0.1839	0.2321	0.2820	0.3342	0.3894	0.4487	0.5132	0.5844	0.6631	0.7498	0.8419
5	7.861	5.859	4.649	3.834	3.244	2.794	2.435	2.138	1.884	1.661	1.462	1.286
6	0.133	0.1779	0.2242	0.2717	0.3209	0.3726	0.4267	0.4852	0.5496	0.6227	0.7082	0.8082

N = 11 VSWR = 1.10

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	171.44	143.61	121.84	103.87	88.48	74.95	62.82	51.76	41.53	31.97	22.96	14.49
1	3.582	2.740	2.247	1.928	1.708	1.549	1.432	1.342	1.272	1.218	1.174	1.138
2	0.1671	0.2266	0.2890	0.3546	0.4232	0.4943	0.5671	0.6402	0.7122	0.7813	0.8460	0.9050
3	7.681	5.712	4.517	3.709	3.121	2.672	2.316	2.027	1.789	1.592	1.430	1.297
4	0.1362	0.1827	0.2302	0.2792	0.3301	0.3834	0.4400	0.5007	0.5668	0.6392	0.7190	0.8059
5	8.24	6.144	4.880	4.029	3.415	2.947	2.576	2.272	2.014	1.789	1.589	1.408
6	0.13	0.1780	0.2241	0.2714	0.3200	0.3706	0.4236	0.4799	0.5407	0.6078	0.6842	0.7729

N = 11 VSWR = 1.20

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	177.08	149.25	127.48	109.51	94.12	80.60	68.46	57.40	47.17	37.61	28.59	20.02
1	4.323	3.286	2.675	2.275	1.996	1.792	1.639	1.520	1.427	1.352	1.291	1.240
2	0.1628	0.2200	0.2796	0.3418	0.4068	0.4745	0.5444	0.6158	0.6878	0.7589	0.8280	0.8936
3	8.319	6.195	4.909	4.041	3.412	2.932	2.552	2.242	1.986	1.771	1.590	1.439
4	0.1388	0.1861	0.2343	0.2838	0.3348	0.3880	0.4439	0.5032	0.5668	0.6359	0.7113	0.7938
5	8.77	6.546	5.203	4.300	3.649	3.155	2.764	2.444	2.176	1.944	1.739	1.555
6	0.14	0.1825	0.2297	0.2778	0.3273	0.3784	0.4317	0.4877	0.5474	0.6120	0.6837	0.7650

N = 11 VSWR = 1.50

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	184.07	156.24	134.47	116.50	101.11	87.59	75.45	64.39	54.16	44.60	35.57	26.98
1	5.811	4.391	3.547	2.990	2.597	2.307	2.085	1.911	1.771	1.657	1.562	1.483
2	0.1690	0.2277	0.2882	0.3510	0.4162	0.4840	0.5544	0.6271	0.7015	0.7771	0.8529	0.9279
3	9.648	7.194	5.711	4.712	3.991	3.442	3.008	2.655	2.362	2.114	1.903	1.723
4	0.1515	0.2030	0.2554	0.3089	0.3639	0.4207	0.4799	0.5420	0.6079	0.6782	0.7541	0.8365
5	9.99	7.462	5.935	4.910	4.171	3.612	3.170	2.812	2.512	2.256	2.031	1.831
6	0.15	0.2005	0.2520	0.3046	0.3585	0.4139	0.4714	0.5312	0.5943	0.6614	0.7340	0.8141

N = 11 VSWR = 2.00

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	188.85	161.01	139.24	121.27	105.88	92.36	80.22	69.16	58.93	49.37	40.34	31.74
1	7.549	5.687	4.576	3.839	3.317	2.929	2.630	2.393	2.202	2.044	1.913	1.801
2	0.1876	0.2522	0.3186	0.3871	0.4580	0.5316	0.6079	0.6868	0.7683	0.8518	0.9368	1.022
3	11.353	8.471	6.730	5.560	4.716	4.074	3.568	3.157	2.816	2.527	2.280	2.067
4	0.1729	0.2315	0.2911	0.3519	0.4142	0.4784	0.5449	0.6144	0.6875	0.7650	0.8480	0.9372
5		8.70	6.923	5.730	4.871	4.220	3.708	3.293	2.947	2.652	2.396	2.168
6		0.230	0.2884	0.3483	0.4097	0.4726	0.5379	0.6056	0.6764	0.7512	0.8312	0.9181

TABLE 12
Step Impedances of 12-Element Filters

N = 12 VSWR = 1.05

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	184.16	153.80	130.05	110.44	93.66	78.90	65.66	53.59	42.44	32.01	22.18	12.99
1	3.061	2.360	1.952	1.692	1.514	1.389	1.297	1.229	1.177	1.137	1.106	1.081
2	0.1756	0.2391	0.3060	0.3765	0.4501	0.5257	0.6017	0.6763	0.7472	0.8126	0.8710	0.9216
3	7.232	5.369	4.237	3.469	2.909	2.481	2.142	1.869	1.647	1.467	1.323	1.209
4	0.1360	0.1826	0.2304	0.2797	0.3313	0.3858	0.4441	0.5073	0.5765	0.6526	0.7356	0.8237
5	7.932	5.915	4.695	3.874	3.280	2.827	2.466	2.169	1.917	1.696	1.500	1.325
6	0.131	0.1756	0.2211	0.2678	0.3161	0.3663	0.4191	0.4754	0.5366	0.6050	0.6839	0.7773

N = 12 VSWR = 1.10

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	189.98	159.61	135.87	116.26	99.47	84.72	71.48	59.41	48.26	37.83	27.98	18.65
1	3.594	2.750	2.255	1.934	1.713	1.554	1.436	1.346	1.276	1.221	1.177	1.142
2	0.1664	0.2257	0.2878	0.3529	0.4211	0.4917	0.5640	0.6366	0.7080	0.7765	0.8405	0.8987
3	7.715	5.738	4.539	3.728	3.139	2.688	2.331	2.042	1.803	1.606	1.444	1.312
4	0.1354	0.1817	0.2289	0.2775	0.3280	0.3808	0.4367	0.4965	0.5613	0.6320	0.7093	0.7928
5	8.294	6.188	4.916	4.060	3.443	2.973	2.601	2.296	2.039	1.815	1.618	1.440
6	0.131	0.1763	0.2219	0.2685	0.3164	0.3661	0.4179	0.4727	0.5313	0.5954	0.6674	0.7505

N = 12 VSWR = 1.20

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	195.62	165.26	141.51	121.90	105.12	90.36	77.12	65.05	53.90	43.47	33.62	24.25
1	4.334	3.295	2.681	2.280	2.001	1.797	1.643	1.524	1.430	1.355	1.294	1.244
2	0.1623	0.2194	0.2787	0.3407	0.4054	0.4727	0.5422	0.6132	0.6847	0.7553	0.8238	0.8886
3	8.346	6.216	4.926	4.056	3.425	2.944	2.563	2.254	1.997	1.782	1.602	1.452
4	0.1383	0.1854	0.2333	0.2825	0.3333	0.3861	0.4415	0.5002	0.5630	0.6309	0.7046	0.7847
5	8.91	6.580	5.231	4.324	3.671	3.175	2.783	2.463	2.195	1.964	1.761	1.578
6	0.14	0.1813	0.2280	0.2756	0.3246	0.3751	0.4275	0.4825	0.5407	0.6032	0.6719	0.7492

N = 12 VSWR = 1.50

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	202.61	172.25	148.58	128.89	112.11	97.35	84.11	72.04	60.89	50.46	40.61	31.22
1	5.821	4.399	3.553	2.995	2.601	2.311	2.089	1.914	1.774	1.660	1.565	1.486
2	0.1687	0.2272	0.2876	0.3502	0.4153	0.4829	0.5530	0.6253	0.6995	0.7747	0.8499	0.9242
3	9.668	7.209	5.724	4.723	4.001	3.451	3.017	2.663	2.370	2.123	1.912	1.732
4	0.1512	0.2025	0.2547	0.3080	0.3628	0.4194	0.4783	0.5400	0.6053	0.6750	0.7499	0.8307
5		7.49	5.955	4.928	4.187	3.626	3.184	2.825	2.526	2.270	2.046	1.848
6		0.200	0.2509	0.3031	0.3566	0.4116	0.4684	0.5276	0.5897	0.6555	0.7262	0.8037

N = 12 VSWR = 2.00

BW	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	207.38	177.02	153.27	133.66	116.88	102.12	88.88	76.81	65.66	55.23	45.38	35.99
1	7.559	5.694	4.581	3.844	3.321	2.933	2.633	2.397	2.205	2.048	1.916	1.804
2	0.1873	0.2519	0.3181	0.3865	0.4573	0.5307	0.6067	0.6855	0.7667	0.8499	0.9344	1.019
3	11.370	8.484	6.741	5.570	4.724	4.082	3.576	3.164	2.823	2.534	2.287	2.075
4	0.1726	0.2311	0.2905	0.3512	0.4133	0.4773	0.5436	0.6128	0.6855	0.7625	0.8446	0.9328
5		8.72	6.940	5.745	4.884	4.232	3.720	3.304	2.958	2.664	2.408	2.182
6		0.23	0.287	0.3470	0.4081	0.4708	0.5355	0.6026	0.6726	0.7464	0.8250	0.9089

TABLE 13

Step Impedances of 13-Element Filters

N = 13 VSWR = 1.05

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	169.80	144.07	122.83	104.65	88.66	74.32	61.25	49.16	37.86	27.20	17.11
1	2.368	1.959	1.697	1.519	1.393	1.300	1.232	1.179	1.139	1.108	1.083
2	0.2380	0.3046	0.3747	0.4478	0.5229	0.5984	0.6725	0.7430	0.8080	0.8660	0.9161
3	5.394	4.258	3.487	2.926	2.496	2.157	1.883	1.661	1.480	1.336	1.222
4	0.1816	0.2291	0.2781	0.3292	0.3832	0.4408	0.5030	0.5710	0.6453	0.7258	0.8108
5	5.954	4.727	3.902	3.305	2.850	2.489	2.191	1.939	1.720	1.526	1.353
6	0.1741	0.2191	0.2653	0.3129	0.3623	0.4141	0.4691	0.5284	0.5939	0.6685	0.7557
7	6.1	4.811	3.974	3.370	2.912	2.549	2.252	2.001	1.782	1.585	1.401

N = 13 VSWR = 1.10

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	175.62	149.89	128.65	110.47	94.48	80.14	67.07	54.98	43.68	33.01	22.86
1	2.757	2.260	1.939	1.717	1.558	1.439	1.348	1.278	1.223	1.180	1.144
2	0.2249	0.2868	0.3517	0.4195	0.4898	0.5616	0.6338	0.7048	0.7729	0.8364	0.8940
3	5.758	4.556	3.742	3.152	2.700	2.343	2.053	1.814	1.617	1.455	1.323
4	0.1809	0.2280	0.2763	0.3264	0.3789	0.4343	0.4935	0.5574	0.6269	0.7025	0.7836
5	6.219	4.941	4.082	3.463	2.991	2.618	2.313	2.056	1.833	1.637	1.462
6	0.175	0.2203	0.2665	0.3140	0.3631	0.4143	0.4681	0.5255	0.5877	0.6567	0.7356
7		5.01	4.140	3.515	3.040	2.666	2.360	2.104	1.883	1.687	1.506

N = 13 VSWR = 1.20

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	181.26	155.54	134.30	116.11	100.13	85.79	72.71	60.62	49.32	38.65	28.49
1	3.301	2.687	2.285	2.005	1.800	1.646	1.527	1.433	1.357	1.296	1.246
2	0.2188	0.2780	0.3398	0.4043	0.4713	0.5406	0.6112	0.6823	0.7526	0.8206	0.8849
3	5.232	4.139	4.067	3.435	2.954	2.572	2.262	2.005	1.791	1.611	1.461
4	0.1848	0.2326	0.2816	0.3322	0.3847	0.4397	0.4980	0.5602	0.6273	0.6999	0.7783
5	6.604	5.250	4.341	3.686	3.189	2.796	2.476	2.208	1.978	1.775	1.595
6	0.180	0.2268	0.2742	0.3228	0.3729	0.4248	0.4791	0.5364	0.5977	0.6645	0.7390
7		5.31	4.387	3.727	3.227	2.833	2.513	2.245	2.016	1.815	1.633

N = 13 VSWR = 1.50

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	188.25	162.53	141.29	123.10	107.12	92.78	79.70	67.61	56.31	45.64	35.48
1	4.405	3.558	2.999	2.605	2.314	2.091	1.917	1.777	1.662	1.568	1.489
2	0.2269	0.2872	0.3497	0.4146	0.4820	0.5519	0.6240	0.6979	0.7728	0.8477	0.9215
3	7.221	5.733	4.732	4.008	3.458	3.023	2.670	2.376	2.129	1.919	1.739
4	0.2021	0.2542	0.3074	0.3620	0.4184	0.4771	0.5386	0.6035	0.6727	0.7468	0.8266
5	7.505	5.970	4.940	4.198	3.636	3.194	2.835	2.535	2.279	2.057	1.859
6	0.199	0.2500	0.3021	0.3553	0.4100	0.4665	0.5253	0.5868	0.6518	0.7213	0.7970
7		6.00	4.973	4.228	3.665	3.221	2.862	2.562	2.308	2.086	1.889

N = 13 VSWR = 2.00

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	193.02	167.30	146.06	127.87	111.89	97.55	84.47	72.38	61.09	50.41	40.25
1	5.700	4.586	3.848	3.325	2.936	2.636	2.399	2.208	2.050	1.918	1.807
2	0.2516	0.3178	0.3861	0.4567	0.5300	0.6059	0.6845	0.7654	0.8483	0.9325	1.017
3	8.494	6.749	5.577	4.730	4.088	3.581	3.170	2.828	2.539	2.293	2.081
4	0.2308	0.2901	0.3506	0.4126	0.4765	0.5426	0.6116	0.6840	0.7606	0.8422	0.9296
5	8.737	6.953	5.755	4.893	4.241	3.728	3.312	2.966	2.672	2.417	2.191
6	0.228	0.2867	0.3462	0.4071	0.4695	0.5339	0.6007	0.6703	0.7434	0.8210	0.9046
7		7.0	5.78	4.919	4.265	3.751	3.335	2.989	2.696	2.442	2.217

TABLE 14

Step Impedances of 14-Element Filters

N = 14 VSWR = 1.05

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	185.81	158.10	135.23	115.44	98.43	82.99	68.90	55.89	43.72	32.23	21.31
1	2.374	1.964	1.701	1.522	1.395	1.303	1.234	1.181	1.141	1.110	1.085
2	0.2372	0.3035	0.3732	0.4460	0.5207	0.5959	0.6696	0.7398	0.8045	0.8622	0.9120
3	5.414	4.274	3.501	2.939	2.508	2.168	1.894	1.671	1.490	1.346	1.231
4	0.1809	0.2281	0.2769	0.3277	0.3812	0.4383	0.4998	0.5669	0.6399	0.7187	0.8014
5	5.983	4.751	3.922	3.323	2.867	2.505	2.207	1.956	1.737	1.545	1.374
6	0.1731	0.2178	0.2635	0.3107	0.3596	0.4108	0.4649	0.5229	0.5866	0.6582	0.7410
7	6.1	4.850	4.010	3.402	2.941	2.577	2.280	2.029	1.813	1.618	1.438

N = 14 VSWR = 1.10

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	191.63	163.92	141.05	121.46	104.25	88.80	74.72	61.71	49.54	38.05	27.10
1	2.763	2.265	1.943	1.721	1.560	1.441	1.351	1.281	1.225	1.182	1.146
2	0.2244	0.2860	0.3507	0.4182	0.4882	0.5598	0.6317	0.7024	0.7701	0.8333	0.8905
3	5.774	4.568	3.754	3.162	2.710	2.352	2.061	1.823	1.625	1.463	1.331
4	0.1804	0.2272	0.2754	0.3253	0.3774	0.4325	0.4912	0.5545	0.6232	0.6975	0.7770
5	6.241	4.960	4.099	3.477	3.005	2.631	2.325	2.068	1.847	1.651	1.478
6	0.1744	0.2193	0.2652	0.3124	0.3611	0.4118	0.4650	0.5215	0.5825	0.6496	0.7255
7		5.04	4.168	3.540	3.063	2.688	2.382	2.126	1.906	1.712	1.534

N = 14 VSWR = 1.20

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	197.27	169.56	146.69	127.11	109.89	94.45	80.36	67.35	55.18	43.69	32.74
1	3.307	2.691	2.288	2.008	1.803	1.648	1.529	1.435	1.359	1.298	1.248
2	0.2184	0.2775	0.3391	0.4034	0.4703	0.5393	0.6097	0.6805	0.7505	0.8181	0.8820
3	5.244	4.149	3.476	3.443	2.961	2.579	2.269	2.012	1.797	1.617	1.468
4	0.1844	0.2321	0.2810	0.3313	0.3836	0.4384	0.4964	0.5582	0.6247	0.6965	0.7737
5	6.621	5.265	4.354	3.697	3.199	2.806	2.486	2.217	1.987	1.786	1.607
6	0.180	0.2260	0.2732	0.3215	0.3713	0.4229	0.4768	0.5335	0.5940	0.6595	0.7320
7		5.32	4.408	3.746	3.245	2.850	2.530	2.262	2.034	1.834	1.654

N = 14 VSWR = 1.50

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	204.26	176.55	153.68	134.09	116.88	101.44	87.35	74.34	62.17	50.68	39.73
1	4.409	3.561	3.002	2.608	2.316	2.094	1.919	1.779	1.664	1.570	1.491
2	0.2266	0.2868	0.3492	0.4140	0.4813	0.5510	0.6230	0.6967	0.7713	0.8459	0.9194
3	7.230	5.741	4.738	4.014	3.463	3.028	2.675	2.381	2.134	1.924	1.745
4	0.2018	0.2538	0.3069	0.3614	0.4177	0.4762	0.5374	0.6021	0.6709	0.7446	0.8236
5	7.52	5.981	4.949	4.207	3.644	3.201	2.842	2.542	2.286	2.064	1.867
6	0.20	0.2495	0.3013	0.3544	0.4089	0.4652	0.5237	0.5848	0.6492	0.7180	0.7925
7		6.0	4.99	4.243	3.678	3.234	2.874	2.575	2.320	2.100	1.904

N = 14 VSWR = 2.00

BW	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	209.03	181.32	158.45	138.87	121.65	106.21	92.13	79.11	66.94	55.45	44.50
1	5.704	4.589	3.851	3.327	2.938	2.638	2.401	2.210	2.052	1.920	1.809
2	0.2514	0.3175	0.3857	0.4563	0.5294	0.6052	0.6836	0.7644	0.8472	0.9311	1.015
3	8.502	6.756	5.582	4.735	4.092	3.584	3.174	2.832	2.543	2.297	2.085
4	0.2305	0.2898	0.3502	0.4122	0.4759	0.5419	0.6107	0.6829	0.7592	0.8404	0.9272
5	8.74	6.961	5.763	4.900	4.247	3.734	3.318	2.972	2.678	2.423	2.198
6	0.23	0.286	0.3456	0.4063	0.4686	0.5328	0.5993	0.6686	0.7413	0.8184	0.9010
7			5.79	4.930	4.276	3.761	3.345	2.999	2.706	2.453	2.229

TABLE 15

STEP IMPEDANCES OF 15-ELEMENT FILTERS

N = 15 VSWR = 1.05

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	172.13	147.62	126.64	108.19	91.65	76.56	62.61	49.58	37.26	25.54
1	1.968	1.704	1.525	1.398	1.305	1.236	1.183	1.143	1.111	1.087
2	0.3026	0.3721	0.4446	0.5190	0.5938	0.6673	0.7372	0.8017	0.8592	0.9088
3	4.287	3.513	2.949	2.518	2.177	1.902	1.679	1.498	1.353	1.239
4	0.2273	0.2759	0.3264	0.3797	0.4363	0.4974	0.5637	0.6358	0.7134	0.7944
5	4.769	3.968	3.338	2.888	2.517	2.220	1.968	1.750	1.559	1.390
6	0.2167	0.2623	0.3091	0.3576	0.4083	0.4618	0.5190	0.5814	0.6511	0.7306
7	4.881	4.035	3.425	2.962	2.597	2.299	2.049	1.833	1.641	1.464
8	0.214	0.2596	0.3058	0.3535	0.4031	0.4552	0.5105	0.5702	0.6365	0.7129

N = 15 VSWR = 1.10

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	177.99	153.44	132.46	114.01	97.47	82.38	68.43	55.40	43.08	31.35
1	2.269	1.946	1.723	1.563	1.443	1.353	1.282	1.227	1.183	1.148
2	0.2854	0.3499	0.4172	0.4870	0.5583	0.6300	0.7004	0.7679	0.8308	0.8878
3	4.579	3.763	3.170	2.717	2.359	2.068	1.829	1.632	1.470	1.338
4	0.2267	0.2747	0.3244	0.3763	0.4311	0.4895	0.5523	0.6203	0.6938	0.7720
5	4.974	4.111	3.488	3.015	2.641	2.336	2.078	1.856	1.662	1.489
6	0.2185	0.2642	0.3112	0.3596	0.4099	0.4627	0.5186	0.5788	0.6446	0.7185
7	5.06	4.188	3.557	3.080	2.703	2.397	2.141	1.922	1.729	1.554
8	0.22	0.2621	0.3086	0.3565	0.4060	0.4578	0.5123	0.5705	0.6338	0.7048

N = 15 VSWR = 1.20

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	183.59	159.08	138.10	119.65	103.11	88.02	74.08	61.04	48.72	36.99
1	2.694	2.291	2.010	1.805	1.650	1.531	1.436	1.361	1.300	1.250
2	0.2770	0.3385	0.4027	0.4694	0.5382	0.6084	0.6790	0.7488	0.8161	0.8797
3	4.957	4.083	3.450	2.967	2.585	2.274	2.017	1.803	1.623	1.473
4	0.2317	0.2804	0.3307	0.3828	0.4374	0.4951	0.5566	0.6227	0.6938	0.7702
5	5.276	4.364	3.706	3.207	2.813	2.493	2.225	1.995	1.794	1.616
6	0.2254	0.2725	0.3206	0.3702	0.4216	0.4751	0.5314	0.5913	0.6560	0.7271
7	5.34	4.423	3.760	3.257	2.862	2.541	2.274	2.046	1.847	1.668
8	0.225	0.2710	0.3187	0.3678	0.4186	0.4714	0.5267	0.5852	0.6480	0.7169

N = 15 VSWR = 1.50

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	190.58	166.07	145.09	126.64	110.10	95.01	81.07	68.03	55.71	43.98
1	3.564	3.005	2.610	2.318	2.095	1.920	1.780	1.666	1.571	1.492
2	0.2866	0.3488	0.4135	0.4807	0.5504	0.6222	0.6957	0.7701	0.8445	0.9177
3	5.747	4.744	4.019	3.468	3.032	2.679	2.385	2.138	1.928	1.749
4	0.2535	0.3065	0.3610	0.4171	0.4755	0.5366	0.6010	0.6696	0.7428	0.8213
5	5.989	4.956	4.213	3.650	3.207	2.847	2.547	2.292	2.070	1.874
6	0.2491	0.3008	0.3538	0.4082	0.4643	0.5225	0.5833	0.6474	0.7156	0.7893
7	6.0	4.999	4.253	3.687	3.242	2.882	2.583	2.329	2.109	1.914
8	0.25	0.300	0.3525	0.4065	0.4622	0.5199	0.5800	0.6431	0.7101	0.7821

N = 15 VSWR = 2.00

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	195.35	170.84	149.86	131.42	114.87	99.78	85.84	72.80	60.49	48.75
1	4.592	3.853	3.329	2.940	2.640	2.403	2.211	2.054	1.922	1.811
2	0.3173	0.3854	0.4559	0.5290	0.6047	0.6830	0.7637	0.8462	0.9300	1.014
3	6.761	5.587	4.739	4.096	3.589	3.177	2.835	2.547	2.300	2.089
4	0.2896	0.3499	0.4118	0.4754	0.5413	0.6100	0.6820	0.7581	0.8390	0.9254
5	6.968	5.769	4.906	4.252	3.739	3.322	2.976	2.682	2.427	2.203
6	0.2859	0.3452	0.4058	0.4680	0.5321	0.5984	0.6674	0.7398	0.8165	0.8984
7	7.0	5.80	4.939	4.283	3.769	3.352	3.006	2.713	2.460	2.237
8		0.345	0.4048	0.4666	0.5303	0.5962	0.6647	0.7364	0.8119	0.8925

TABLE 16

STEP IMPEDANCES OF 16-ELEMENT FILTERS

N = 16 VSWR = 1.05

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	186.15	160.01	137.63	117.96	100.31	84.21	69.34	55.43	42.30	29.79
1	1.971	1.707	1.527	1.400	1.307	1.237	1.184	1.144	1.112	1.088
2	0.3019	0.3712	0.4434	0.5176	0.5922	0.6654	0.7351	0.7995	0.8568	0.9062
3	4.298	3.522	2.957	2.525	2.184	1.909	1.686	1.505	1.359	1.245
4	0.2267	0.2751	0.3255	0.3785	0.4348	0.4955	0.5612	0.6326	0.7093	0.7891
5	4.784	3.951	3.349	2.891	2.527	2.229	1.978	1.760	1.569	1.401
6	0.2160	0.2613	0.3079	0.3561	0.4065	0.4595	0.5161	0.5776	0.6459	0.7232
7	4.902	4.054	3.442	2.978	2.612	2.313	2.063	1.848	1.657	1.483
8	0.2134	0.2581	0.3039	0.3511	0.4002	0.4516	0.5059	0.5642	0.6283	0.7012

N = 16 VSWR = 1.10

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	191.97	165.83	143.45	123.78	106.13	90.03	75.16	61.25	48.12	35.60
1	2.272	1.948	1.725	1.565	1.445	1.354	1.284	1.228	1.184	1.149
2	0.2849	0.3492	0.4164	0.4860	0.5571	0.6286	0.6988	0.7661	0.8288	0.8856
3	4.587	3.770	3.176	2.723	2.364	2.074	1.834	1.637	1.475	1.343
4	0.2262	0.2741	0.3237	0.3754	0.4300	0.4881	0.5505	0.6181	0.6909	0.7682
5	4.985	4.121	3.497	3.023	2.648	2.349	2.085	1.864	1.670	1.498
6	0.2179	0.2635	0.3103	0.3585	0.4086	0.4610	0.5165	0.5760	0.6410	0.7133
7	5.08	4.202	3.570	3.092	2.714	2.408	2.152	1.933	1.741	1.568
8	0.22	0.2611	0.3072	0.3547	0.4038	0.4551	0.5089	0.5661	0.6279	0.6966

N = 16 VSWR = 1.20

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	197.62	171.47	149.09	129.42	111.77	95.68	80.80	66.89	53.76	41.25
1	2.697	2.294	2.012	1.807	1.652	1.532	1.438	1.362	1.301	1.251
2	0.2767	0.3381	0.4021	0.4687	0.5374	0.6074	0.6779	0.7474	0.8146	0.8779
3	4.964	4.089	3.455	2.971	2.589	2.278	2.021	1.807	1.627	1.477
4	0.2313	0.2800	0.3301	0.3822	0.4366	0.4941	0.5553	0.6211	0.6918	0.7675
5	5.285	4.371	3.713	3.213	2.819	2.498	2.230	2.001	1.800	1.622
6	0.2250	0.2719	0.3199	0.3694	0.4205	0.4738	0.5298	0.5893	0.653R	0.7236
7	5.35	4.434	3.770	3.267	2.871	2.550	2.282	2.054	1.856	1.679
8	0.23	0.270	0.3176	0.3665	0.4170	0.4694	0.5241	0.5819	0.6437	0.7111

N = 16 VSWR = 1.50

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	204.61	178.46	156.08	136.41	118.76	102.67	87.79	73.88	60.75	48.24
1	3.567	3.007	2.612	2.320	2.097	1.922	1.782	1.667	1.573	1.494
2	0.2863	0.3485	0.4132	0.4803	0.5498	0.6215	0.6949	0.7692	0.8434	0.9163
3	5.752	4.748	4.022	3.471	3.036	2.682	2.388	2.141	1.931	1.752
4	0.2533	0.3062	0.3606	0.4167	0.4749	0.5359	0.6002	0.6685	0.7415	0.8196
5	5.995	4.962	4.218	3.654	3.211	2.851	2.551	2.296	2.074	1.878
6	0.2488	0.3004	0.3533	0.4076	0.4635	0.5216	0.5822	0.6460	0.7139	0.7870
7	6.0	5.008	4.260	3.694	3.249	2.888	2.589	2.335	2.115	1.921
8	0.26	0.300	0.3517	0.4055	0.4610	0.5184	0.5782	0.6409	0.7072	0.7782

N = 16 VSWR = 2.00

BW	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
L(DB)	209.38	183.24	160.85	141.18	123.53	107.44	92.56	78.66	65.52	53.01
1	4.595	3.855	3.331	2.942	2.642	2.404	2.213	2.055	1.923	1.812
2	0.3171	0.3852	0.4556	0.5286	0.6043	0.6825	0.7630	0.8455	0.9291	1.013
3	6.765	5.590	4.742	4.099	3.592	3.180	2.838	2.549	2.303	2.091
4	0.2894	0.3497	0.4115	0.4751	0.5409	0.6095	0.6814	0.7573	0.8380	0.9240
5	6.974	5.773	4.910	4.256	3.742	3.326	2.979	2.685	2.431	2.207
6	0.2856	0.3449	0.4054	0.4675	0.5315	0.5976	0.6665	0.7387	0.8150	0.8966
7	7.0	5.81	4.945	4.289	3.774	3.357	3.011	2.718	2.466	2.243
8		0.345	0.4041	0.4658	0.5293	0.5950	0.6632	0.7345	0.8096	0.8894

TABLE 17

Step Impedances of 17-Element Filters

N = 17 VSWR = 1.05

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	172.41	148.63	127.72	91.87	61.29	34.04
1	1.709	1.529	1.401	1.238	1.145	1.089
2	0.3704	0.4424	0.5164	0.6638	0.7976	0.9042
3	3.529	2.964	2.532	1.915	1.510	1.250
4	0.2745	0.3247	0.3775	0.4939	0.6301	0.7850
5	3.960	3.358	2.899	2.237	1.768	1.410
6	0.2605	0.3070	0.3550	0.4577	0.5747	0.7177
7	4.068	3.454	2.989	2.324	1.859	1.497
8	0.2569	0.3025	0.3494	0.4490	0.5600	0.6931
9	4.10	3.477	3.010	2.343	1.880	1.521

N = 17 VSWR = 1.10

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	178.22	154.44	133.54	97.69	67.11	39.86
1	1.951	1.727	1.566	1.355	1.229	1.150
2	0.3487	0.4157	0.4852	0.6274	0.7646	0.8838
3	3.776	3.182	2.728	2.078	1.641	1.347
4	0.2737	0.3231	0.3747	0.4870	0.6163	0.7652
5	4.128	3.504	3.029	2.348	1.870	1.505
6	0.2629	0.3095	0.3576	0.4597	0.5739	0.7095
7	4.213	3.580	3.101	2.416	1.942	1.578
8	0.2602	0.3061	0.3534	0.4531	0.5630	0.6909
9	4.23	3.598	3.117	2.431	1.958	1.597

N = 17 VSWR = 1.20

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	183.87	160.09	139.18	103.33	72.75	45.50
1	2.295	2.014	1.808	1.533	1.363	1.252
2	0.3377	0.4017	0.4681	0.6066	0.7463	0.8765
3	4.093	3.459	2.975	2.282	1.810	1.481
4	0.2797	0.3297	0.3817	0.4933	0.6198	0.7653
5	4.377	3.718	3.218	2.503	2.005	1.627
6	0.2715	0.3194	0.3687	0.4728	0.5878	0.7209
7	4.443	3.778	3.274	2.556	2.061	1.686
8	0.2694	0.3168	0.3655	0.4679	0.5796	0.7070
9	4.46	3.791	3.286	2.567	2.073	1.701

N = 17 VSWR = 1.50

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	190.86	167.08	146.17	110.32	79.74	52.49
1	3.008	2.613	2.321	1.923	1.668	1.495
2	0.3483	0.4129	0.4799	0.6210	0.7684	0.9152
3	4.751	4.025	3.474	2.684	2.143	1.755
4	0.3040	0.3603	0.4163	0.5354	0.6676	0.8181
5	4.966	4.222	3.658	2.854	2.299	1.882
6	0.3001	0.3529	0.4071	0.5209	0.6450	0.7852
7	5.014	4.265	3.699	2.893	2.340	1.926
8	0.299	0.3511	0.4048	0.5174	0.6393	0.7755
9		4.27	3.707	2.901	2.348	1.937

N = 17 VSWR = 2.00

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	195.63	171.85	150.94	115.09	84.51	57.26
1	3.857	3.333	2.943	2.405	2.056	1.813
2	0.3850	0.4554	0.5283	0.6820	0.8448	1.IH
3	5.593	4.745	4.101	3.182	2.551	2.094
4	0.3495	0.4112	0.4748	0.6090	0.7566	0.9229
5	5.777	4.913	4.259	3.328	2.688	2.210
6	0.3446	0.4051	0.4671	0.5971	0.7379	0.8951
7	5.81	4.950	4.293	3.361	2.722	2.248
8	0.35	0.4037	0.4652	0.5942	0.7332	0.8872
9		4.94	4.299	3.368	2.729	2.256

TABLE 18

Step Impedances of 18-Element Filters

N = 18 VSWR = 1.05

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	184.80	159.62	137.49	99.53	67.15	38.29
1	1.711	1.531	1.403	1.240	1.146	1.090
2	0.3698	0.4416	0.5155	0.6626	0.7961	0.9025
3	3.535	2.969	2.537	1.920	1.514	1.254
4	0.2740	0.3241	0.3767	0.4926	0.6280	0.7816
5	3.968	3.365	2.905	2.243	1.774	1.418
6	0.2599	0.3062	0.3541	0.4563	0.5725	0.7134
7	4.079	3.464	2.998	2.332	1.868	1.507
8	0.2561	0.3014	0.3481	0.4470	0.5568	0.6872
9	4.11	3.492	3.024	2.356	1.894	1.537

N = 18 VSWR = 1.10

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	190.62	165.44	143.31	105.34	72.97	44.11
1	1.952	1.729	1.567	1.356	1.230	1.151
2	0.3482	0.4152	0.4845	0.6265	0.7634	0.8823
3	3.781	3.186	2.732	2.082	1.645	1.351
4	0.2733	0.3226	0.3741	0.4861	0.6148	0.7627
5	4.185	3.569	3.034	2.353	1.875	1.511
6	0.2625	0.3090	0.3569	0.4587	0.5723	0.7065
7	4.222	3.588	3.108	2.423	1.948	1.586
8	0.2596	0.3053	0.3524	0.4516	0.5606	0.6867
9	4.23	3.608	3.128	2.441	1.968	1.609

N = 18 VSWR = 1.20

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	195.26	171.08	148.95	110.99	78.61	49.75
1	2.297	2.015	1.809	1.534	1.364	1.253
2	0.3374	0.4013	0.4676	0.6059	0.7453	0.8753
3	4.097	3.462	2.979	2.285	1.813	1.464
4	0.2794	0.3294	0.3812	0.4926	0.6187	0.7636
5	4.382	3.722	3.222	2.507	2.009	1.632
6	0.2711	0.3190	0.3682	0.4721	0.5866	0.7188
7	4.449	3.783	3.279	2.561	2.066	1.692
8	0.269	0.3162	0.3648	0.4668	0.5779	0.7040
9		3.80	3.294	2.575	2.081	1.710

N = 18 VSWR = 1.50

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	203.25	178.07	155.94	117.98	85.60	56.74
1	3.010	2.615	2.322	1.924	1.669	1.496
2	0.3481	0.4126	0.4796	0.6205	0.7677	0.9143
3	4.754	4.028	3.476	2.686	2.145	1.757
4	0.3058	0.3601	0.4160	0.5349	0.6670	0.8170
5	4.970	4.225	3.661	2.857	2.302	1.885
6	0.2999	0.3526	0.4067	0.5204	0.6441	0.7838
7	5.02	4.270	3.703	2.896	2.343	1.930
8	0.299	0.3507	0.4043	0.5166	0.6381	0.7735
9		4.27	3.713	2.907	2.354	1.943

N = 18 VSWR = 2.00

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	208.02	182.84	160.71	122.75	90.37	61.51
1	3.858	3.334	2.944	2.406	2.057	1.814
2	0.3848	0.4552	0.5281	0.6817	0.8443	1.011
3	5.595	4.747	4.103	3.184	2.553	2.096
4	0.3493	0.4110	0.4745	0.6087	0.7561	0.9220
5	5.780	4.916	4.261	3.330	2.690	2.212
6	0.3444	0.4048	0.4668	0.5966	0.7372	0.8940
7	5.822	4.953	4.297	3.364	2.725	2.251
8	0.343	0.4032	0.4648	0.5935	0.7322	0.8855
9		4.96	4.306	3.372	2.734	2.262

TABLE 19

Step Impedances of 19-Element Filters

N = 19 VSWR = 1.05

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	197.19	170.61	147.25	107.18	73.00	42.55
1	1.713	1.532	1.404	1.240	1.147	1.090
2	0.3692	0.4410	0.5146	0.6615	0.7948	0.9011
3	3.541	2.974	2.541	1.923	1.518	1.257
4	0.2736	0.3236	0.3760	0.4916	0.6263	0.7789
5	3.975	3.371	2.911	2.248	1.780	1.424
6	0.2595	0.3056	0.3533	0.4552	0.5706	0.7101
7	4.088	3.472	3.006	2.339	1.874	1.515
8	0.2554	0.3006	0.3471	0.4455	0.5545	0.6829
9	4.12	3.504	3.035	2.366	1.904	1.550
10	0.26	0.2993	0.3456	0.4432	0.5507	0.6760

N = 19 VSWR = 1.10

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	203.01	176.43	153.07	113.00	78.82	48.36
1	1.954	1.730	1.569	1.357	1.231	1.152
2	0.3478	0.4147	0.4839	0.6257	0.7624	0.8811
3	3.785	3.190	2.735	2.085	1.648	1.354
4	0.2730	0.3223	0.3736	0.4853	0.6136	0.7607
5	4.140	3.514	3.039	2.357	1.879	1.515
6	0.2621	0.3085	0.3564	0.4578	0.5709	0.7042
7	4.229	3.594	3.113	2.428	1.953	1.592
8	0.2590	0.3047	0.3516	0.4505	0.5589	0.6836
9	4.26	3.619	3.136	2.449	1.976	1.618
10	0.257	0.3038	0.3505	0.4487	0.5561	0.6786

N = 19 VSWR = 1.20

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	208.65	182.08	158.71	118.64	84.46	54.01
1	2.298	2.016	1.810	1.535	1.365	1.254
2	0.3371	0.4009	0.4672	0.6053	0.7445	0.8742
3	4.100	3.465	2.981	2.287	1.815	1.486
4	0.2742	0.3291	0.3809	0.4921	0.6179	0.7621
5	4.386	3.726	3.225	2.510	2.012	1.635
6	0.2709	0.3186	0.3678	0.4715	0.5856	0.7171
7	4.455	3.788	3.283	2.565	2.070	1.697
8	0.269	0.3158	0.3642	0.4659	0.5766	0.7018
9	4.4	3.80	3.301	2.581	2.087	1.717
10		0.317	0.3635	0.4646	0.5748	0.6980

N = 19 VSWR = 1.50

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	215.64	189.07	165.70	125.63	91.45	61.00
1	3.011	2.616	2.323	1.925	1.670	1.496
2	0.3479	0.4124	0.4793	0.6201	0.7672	0.9136
3	4.756	4.030	3.478	2.688	2.147	1.759
4	0.3057	0.3599	0.4158	0.5345	0.6664	0.8160
5	4.972	4.227	3.663	2.859	2.304	1.887
6	0.2997	0.3524	0.4064	0.5199	0.6435	0.7827
7	5.022	4.273	3.706	2.899	2.346	1.934
8	0.299	0.3503	0.4039	0.5160	0.6372	0.7719
9		4.28	3.718	2.911	2.358	1.948
10		0.35	0.404	0.5151	0.6357	0.7694

N = 19 VSWR = 2.00

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	220.41	193.84	170.47	130.40	96.23	65.77
1	3.859	3.335	2.945	2.407	2.058	1.815
2	0.3847	0.4550	0.5279	0.6814	0.8439	1.011
3	5.597	4.749	4.105	3.185	2.555	2.097
4	0.3492	0.4109	0.4743	0.6084	0.7556	0.9212
5	5.782	4.918	4.263	3.332	2.692	2.214
6	0.3442	0.4046	0.4666	0.5963	0.7366	0.8931
7	5.824	4.956	4.299	3.366	2.727	2.254
8	0.344	0.4030	0.4644	0.5930	0.7315	0.8843
9		4.96	4.309	3.376	2.738	2.266
10		0.41	0.464	0.5923	0.7303	0.8822

TABLE 20

Step Impedances of 20-Element Filters

N = 20 VSWR = 1.05

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	209.58	181.61	157.02	114.84	78.86	46.80
1	1.714	1.533	1.405	1.241	1.147	1.091
2	0.3668	0.4404	0.5140	0.6605	0.7937	0.8999
3	3.545	2.978	2.545	1.927	1.521	1.260
4	0.2732	0.3231	0.3755	0.4907	0.6249	0.7766
5	3.981	3.376	2.915	2.252	1.784	1.428
6	0.2591	0.3051	0.3527	0.4543	0.5692	0.7074
7	4.094	3.479	3.012	2.344	1.880	1.522
8	0.2551	0.3000	0.3463	0.4443	0.5526	0.6795
9	4.1	3.511	3.043	2.374	1.911	1.559
10	0.27	0.300	0.3445	0.4414	0.5479	0.6709

N = 20 VSWR = 1.10

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	215.40	187.43	162.83	120.66	84.68	52.62
1	1.955	1.731	1.569	1.358	1.232	1.152
2	0.3475	0.4143	0.4834	0.6250	0.7615	0.8800
3	3.788	3.193	2.738	2.087	1.650	1.356
4	0.2727	0.3219	0.3732	0.4847	0.6125	0.7591
5	4.144	3.518	3.042	2.360	1.882	1.519
6	0.2618	0.3082	0.3559	0.4571	0.5699	0.7023
7	4.234	3.599	3.118	2.432	1.958	1.596
8	0.259	0.3043	0.3510	0.4496	0.5575	0.6812
9	4.2	3.62	3.142	2.455	1.982	1.625
10		0.306	0.3498	0.4474	0.5540	0.6749

N = 20 VSWR = 1.20

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	221.05	193.07	168.48	126.30	90.32	58.26
1	2.300	2.017	1.811	1.536	1.366	1.254
2	0.3369	0.4007	0.4669	0.6048	0.7439	0.8734
3	4.103	3.468	2.983	2.289	1.817	1.488
4	0.2790	0.3288	0.3806	0.4916	0.6171	0.7609
5	4.389	3.729	3.228	2.512	2.014	1.638
6	0.2706	0.3184	0.3674	0.4700	0.5848	0.7157
7	4.459	3.792	3.287	2.568	2.073	1.700
8	0.268	0.3154	0.3637	0.4653	0.5756	0.7000
9	4.4	3.81	3.306	2.586	2.091	1.722
10		0.317	0.3628	0.4636	0.5730	0.6954

N = 20 VSWR = 1.50

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	228.04	200.08	175.47	133.29	97.31	65.25
1	3.012	2.617	2.324	1.925	1.671	1.497
2	0.3478	0.4122	0.4791	0.6198	0.7667	0.9129
3	4.758	4.032	3.480	2.690	2.149	1.760
4	0.3055	0.3597	0.4156	0.5342	0.6659	0.8152
5	4.975	4.229	3.665	2.861	2.306	1.889
6	0.2995	0.3522	0.4062	0.5196	0.6429	0.7818
7	5.02	4.276	3.708	2.901	2.348	1.936
8	0.299	0.3502	0.4036	0.5155	0.6364	0.7707
9		4.28	3.720	2.914	2.362	1.952
10		0.36	0.404	0.5144	0.6346	0.7675

N = 20 VSWR = 2.00

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	232.81	204.83	180.24	138.06	102.08	70.02
1	3.860	3.336	2.946	2.408	2.058	1.815
2	0.3846	0.4549	0.5277	0.6811	0.8435	1.010
3	5.599	4.750	4.106	3.187	2.556	2.098
4	0.3491	0.4107	0.4742	0.6081	0.7552	0.9206
5	5.784	4.919	4.265	3.334	2.694	2.216
6	0.3441	0.4045	0.4664	0.5960	0.7362	0.8924
7	5.82	4.958	4.301	3.368	2.729	2.256
8	0.35	0.4030	0.4642	0.5926	0.7309	0.8833
9		4.95	4.31	3.379	2.740	2.269
10		0.42	0.465	0.5917	0.7293	0.8807

TABLE 21

STEP IMPEDANCES OF 21-ELEMENT FILTERS

N = 21 VSWR = 1.05

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	221.98	192.60	166.78	122.49	84.72	51.05
1	1.715	1.534	1.406	1.242	1.148	1.091
2	0.3684	0.4399	0.5134	0.6598	0.7928	0.8989
3	3.549	2.982	2.548	1.930	1.523	1.262
4	0.2729	0.3227	0.3750	0.4900	0.6237	0.7747
5	3.985	3.380	2.919	2.256	1.788	1.433
6	0.2587	0.3047	0.3522	0.4535	0.5679	0.7052
7	4.101	3.484	3.016	2.349	1.884	1.527
8	0.2545	0.2994	0.3457	0.4433	0.5511	0.6768
9	4.141	3.520	3.050	2.380	1.917	1.566
10	0.2529	0.2979	0.3436	0.4400	0.5458	0.6671
11	4.2	3.61	3.056	2.388	1.926	1.576

N = 21 VSWR = 1.10

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	227.80	198.42	172.60	128.31	90.54	56.87
1	1.956	1.732	1.570	1.359	1.232	1.153
2	0.3472	0.4139	0.4830	0.6244	0.7608	0.8792
3	3.791	3.196	2.741	2.090	1.652	1.358
4	0.2725	0.3216	0.3729	0.4841	0.6117	0.7577
5	4.148	3.521	3.045	2.363	1.885	1.522
6	0.2616	0.3078	0.3555	0.4566	0.5690	0.7007
7	4.238	3.603	3.122	2.435	1.961	1.600
8	0.2585	0.3038	0.3505	0.4489	0.5564	0.6793
9	4.2	3.630	3.147	2.460	1.986	1.631
10	0.27	0.304	0.3491	0.4464	0.5524	0.6721
11			3.14	2.466	1.993	1.638

N = 21 VSWR = 1.20

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	233.44	204.06	178.24	133.95	96.18	62.51
1	2.301	2.018	1.812	1.537	1.366	1.255
2	0.3367	0.4004	0.4666	0.6044	0.7433	0.8726
3	4.106	3.470	2.985	2.291	1.819	1.490
4	0.2788	0.3286	0.3803	0.4913	0.6165	0.7599
5	4.392	3.731	3.230	2.514	2.016	1.640
6	0.2704	0.3181	0.3672	0.4705	0.5841	0.7146
7	4.462	3.795	3.290	2.571	2.076	1.703
8	0.268	0.3151	0.3634	0.4647	0.5748	0.6986
9	4.4	3.81	3.309	2.589	2.095	1.726
10		0.316	0.3624	0.4629	0.5718	0.6934
11			3.30	2.593	2.100	1.732

N = 21 VSWR = 1.50

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	240.43	211.05	185.23	140.94	103.17	69.50
1	3.013	2.617	2.325	1.926	1.671	1.498
2	0.3477	0.4121	0.4789	0.6195	0.7663	0.9124
3	4.760	4.033	3.481	2.691	2.150	1.762
4	0.3054	0.3695	0.4354	0.5340	0.6655	0.8145
5	4.977	4.231	3.667	2.862	2.307	1.891
6	0.2994	0.3620	0.4060	0.5193	0.6424	0.7810
7	5.028	4.278	3.710	2.903	2.350	1.938
8	0.298	0.3499	0.4033	0.5151	0.6359	0.7698
9		4.29	3.724	2.917	2.364	1.955
10		0.35	0.403	0.5138	0.6338	0.7661
11			3.71	2.921	2.368	1.959

N = 21 VSWR = 2.00

BW	0.60	0.70	0.80	1.00	1.20	1.40
L(DB)	245.20	215.83	190.00	145.71	107.94	74.27
1	3.861	3.337	2.946	2.408	2.059	1.816
2	0.3845	0.4548	0.5275	0.6809	0.8432	1.010
3	5.601	4.752	4.108	3.188	2.557	2.100
4	0.3490	0.4106	0.4740	0.6079	0.7549	0.9200
5	5.786	4.921	4.266	3.335	2.695	2.218
6	0.3440	0.4043	0.4662	0.5957	0.7358	0.8917
7	5.82	4.960	4.303	3.369	2.731	2.258
8	0.35	0.4029	0.4640	0.5923	0.7304	0.8825
9		4.9	4.31	3.381	2.743	2.271
10		0.42	0.465	0.591	0.729	0.880
11			4.2	3.382	2.745	2.275

Synthesis of Symmetrical TEM-Mode Directional Couplers

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Abstract—Exact synthesis procedures are derived for symmetrical three-section and five-section TEM-mode directional couplers. These synthesis procedures are based on the equivalence between the theory of directional couplers and stepped quarter-wavelength filters as previously described by Levy and Young. Explicit formulas for the parameters of three-section couplers are presented.

A realizable insertion-loss function is derived for the five-section coupler resulting in an equal-ripple response. Although this function has an equal-ripple characteristic, it is not expressible in terms of Chebyshev polynomials. Results obtained for the five-section coupler show considerable improvement in bandwidth over a three-section coupler. For example, a five-section coupler of -3 ± 0.5 dB has a bandwidth of 9.6:1 as compared with 5.8:1 for a three-section coupler of -3 ± 0.5 dB.

A five-section coupler of -10 ± 0.5 dB was designed on this theoretical basis for the 555–4000 Mc band, and the measured performance shows good agreement with the theoretical coupling response, yielding a minimum directivity of 18.0 dB at 3.7 Gc.

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